Baseline and Monitoring Methodology for Project Activities that Reduce Emissions from Deforestation on Degrading Land

A methodology proposed for the Voluntary Carbon Standard

Version 2.0 (revised after 1st comments from TUV)

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This methodology is based in part on a number of previous publications. Therefore, the authors of this methodology would like to explicitly acknowledge the prior work done by the authors of the "*Sourcebook for LULUCF*", published by the BioCarbon fund and Winrock International, "*REDD in Developing Countries: A Sourcebook of Methods and Procedures for Monitoring, Measuring, and Reporting*" published by the GOFC GOLD; and the "*Methodology for Estimating Reductions of GHG Emissions from Mosaic Deforestation*" from the BioCarbon fund (RED-NM-001). Sections of this methodology are based on approved CDM methodologies for afforestation and reforestation (most notably AR-AM0003, AR-AM0004, and AR-AM0006), tools from the CDM Executive Board, and the Good Practice Guidance from the IPCC (versions from 2000, 2003, and 2006).

Introduction and Definitions

Human-induced deforestation and forest degradation are significant contributors to the accumulation of greenhouse gases (GHGs) in the atmosphere (Achard et al., 2002). However, certain activities can decrease deforestation rates and effectively prevent or reduce the GHG emissions being released to the atmosphere, thus enabling the generation of carbon credits. Projects in which such activities are implemented are referred to as Reduced Emissions from Deforestation and Degradation (REDD) projects. Deforestation under this methodology includes both the rapid conversion from forest-land to non-forest land, and the progressive gradual degradation of forest land. This methodology provides a transparent and reliable procedure for calculating GHG emission estimates that are real, scientifically defensible, and verifiable, as described by the ISO 14064-2:2006 standard (clause 3). This methodology is relevant for projects that reduce emissions from unplanned mosaic deforestation and forest degradation, as defined in VCS 2007.1, 2008 p13. The following table summarizes the main methodological aspects.

SUMMARY OF THE METHODOLOGY
• REDD credits are calculated by subtracting *ex-ante* changes in baseline carbon stocks, *ex-post* monitored emissions from leakage, and *ex-post* monitored emission sources from the *ex-post* monitored changes in carbon stocks in the project areas • Baseline emissions in the project area are calculated based on historical deforestation or forest degradation rates in a reference region that is similar to the project area. • Credits from avoided deforestation and avoided forest degradation are treated separately. When changes in forest biomass cannot be measured with sufficient accuracy, credits from avoided forest degradation must be excluded. Credits from avoided deforestation may still be included. • The quantification of baseline deforestation/degradation rates is based on field-calibrated remote sensing analyses over a historical reference period. Credits from avoided deforestation are discounted based on the accuracy of observing forest vs. non-forest. Credits from avoided degradation are discounted based on the accuracy of observing individual forest biomass classes. • Carbon stock densities are quantified by permanent sampling plots on forest lands or temporary sampling plots on non-forest lands. Net emission reductions are discounted based on the attained precision of the biomass measurements. If the forest biomass density cannot be measured with sufficient precision, the project is not eligible. • Leakage is monitored and quantified using a leakage belt approach or a factor approach, depending on the driver. Emission reductions from avoiding timber logging must be discounted for market leakage. • While assisted reforestation is not allowed under the VCS AFOLU guidance for REDD projects, natural reforestation and regeneration are included in the baseline and project scenarios. This is achieved by applying the empirically observed baseline regeneration and reforestation rates in the reference region to the project and baseline scenarios. • Projects may include assisted natural regeneration activities on degraded areas. The quantification of the GHG benefits from assisted natural regeneration must follow the CDM-approved methodology AR-ACM0001 version 3.

Definitions

The definitions below are consistent with or complement the definitions in the VCS AFOLU guidance (VCS 2007.1, 2008 p 40-43).

Greenhouse Gases, Sources, and Sinks

The term **greenhouse gas (GHG)** refers to an atmospheric gas contributing to global climate change. There are three biogenic greenhouse gases included in this methodology, which can be emitted from sources or sequestered in sinks (Table 1).

Table 1. Emissions and sinks of greenhouse gases

Greenhouse Gas	Examples of Sources	Examples of Sinks
Carbon dioxide (CO_2)	Forest degradation Deforestation Fuel use in combustion engines	Forest regeneration
Nitrous oxide (N_2O)	Forest fires Nitrogen fertilizer Manure management	None
Methane (CH_4)	Forest fires Livestock (mostly ruminants) Manure management	None

Net Emission Reductions (NERs) are the net GHG benefits generated by the REDD project. The Voluntary Carbon Units (VCUs) are the NERs that are released after transferring the adequate amount of NERs to a buffer account according to before discounting credits according to the VCS AFOLUA non-permanence risk analysis.

Geographical boundaries

This methodology uses three geographical distinctions for land.

The **project area** is the geographical area where the project participants will implement activities to reduce deforestation. The project area may be contiguous or consist of multiple smaller adjacent and non-adjacent project areas (referred to as **discrete project area parcels**).

Leakage is the net change in carbon stocks and/or the increase in permanent GHG emissions occurring outside the project area but that are attributable to the REDD project activity. Leakage occurs when GHG emissions increase outside of the project area as a result of project measures. This increase in GHG emissions can be due to increased deforestation, increased forest degradation, or the increased emission of non-biomass GHG emissions. The area where leakage occurs around an individual discrete project area parcel is referred to as a **leakage belt**. Adjacent discrete project parcels will share a leakage belt. The **leakage area** is the sum individual leakage belts. The leakage area does not have to be contiguous.

The **reference region** is the region from which historical and current deforestation and forest degradation quantities and trends are obtained. This information is required to predict future deforestation and degradation quantities in the absence of project activities (i.e. baseline scenario). Before the start of the project (i.e. during the historical reference period) the reference region includes the project and leakage areas. After the project has started (i.e. during the crediting period) the reference region excludes the project and leakage areas to serve as a reference for determining deforestation and forest degradation rates in the absence of project activities.

Scenarios

The **baseline scenario** represents the hypothetical situation in which the proposed project activities are not implemented; the baseline scenario refers to the business-as-usual situation in absence of the proposed REDD project activity.

The **project scenario** represents the situation in which the proposed project activities are implemented according to the proposed project actions. The emission reductions generated by the REDD project area are calculated by subtracting the net GHG emissions under the baseline scenario from the net GHG emissions under the project scenario taking leakage into account.

Temporal Boundaries

The **crediting period start date** is equal to the **project start date** and is the date when the first project activity is implemented for which net emission reductions are claimed.

The **historical reference period** is a fixed time period preceding the starting date of the proposed REDD project during which the magnitude of deforestation in the reference region is quantified, and the agents and drivers of deforestation are identified. This analysis is the basis for the estimation of future deforestation trends and is used to calculate the baseline GHG emissions for the first baseline validation period. The historical reference period must start at least three years before the starting date of the project. The duration may range between 3 and 15 years.

The **crediting period** is the time period during which project activities are implemented and VCUs are generated. The duration of the crediting period can range between 20 and 100 years (VCS 2007.1, 2008 p 17). The crediting period begins on the project start date.

The project actions and conditions must be monitored and compiled in monitoring reports. Only after a third party **verification** of a monitoring report, can VCUs be issued. The frequency and dates of verification must be fixed and must be included in the PD.

The **baseline validation period** is the period during which the *ex-ante* calculation of net GHG emissions under the baseline scenario is valid. After the baseline validation period expires, a new *ex-ante* baseline needs to be calculated and validated by a VCS verifier. This baseline must be updated at least every ten years (VCS 2007.1, 2008 p 22) and this update needs to coincide with a verification event but may occur less frequently than verification. The frequency and dates of baseline updates must be fixed and must be included in the PD.

Land Use and Land Cover (LULC) Classes and Forest Strata

In this methodology units of land are allocated to different **land use and land cover** (LULC) classes. The forest LULC classes is further divided into more narrow forest strata according to biomass density, forest type or management. These definitions are consistent with the IPCC GPG-LULCF 2003 and the requirements of Articles 3.3 and 3.4 of the Kyoto Protocol. The following definitions are in accordance with Chapter 2 of the IPCC GPG-LULUCF 2003.

Under this methodology, a **forest** is defined as following:

- If the Designated National Authority (DNA) of the country where the REDD project activity will be implemented has set the thresholds for defining a forest according to decisions 11/CP.7 and 11/CP.9, these should be followed by the project proponents. The DNA definition can be checked on the CDM UNFCCC website at http://cdm.unfccc.int/DNA/index.html.
- If the DNA has not formally decided on a forest definition, the FAO definition should be used

> *Forest includes natural forests and forest plantations. It is used to refer to land with a tree canopy cover of more than 10 percent and area of more than 0.5 ha. Forests are determined both by the presence of trees and the absence of other predominant land uses. The trees should be able to reach a minimum height of 5 m.*

(http://www.fao.org/DOCREP/004/Y1997E/y1997e1m.htm#bm58)

Once the project has started, the forest definition used in the project cannot be changed, even if the DNA decides on a different definition from the definition in effect when the project was validated.

Temporarily un-stocked forests are areas that have previously met the criteria for forest land, do not meet these criteria at present, but are expected to regenerate and become forest land again. Such land includes harvested areas in managed forests or forest land that was affected by a fire or a hurricane, on the condition that this land will regenerate to forest land (and meet the forest definition criteria again) within a pre-defined period referred to as the **maximal period of temporarily un-stocked**. See IPCC GPG LULUCF 2003, Chapter. 4.2.6.2.1 for further reference.

The forest LULC class is further sub-divided into more narrow **forest strata** according to the carbon stock density, native forest type, past and future management, landscape position, biophysical properties, and the degree of past disturbance.

Cropland includes arable and tillage land and agro-forestry systems where vegetation does not the meet the forest definition.

Grassland includes managed and unmanaged rangeland, pasture land, wild land, recreational areas, and silvo-pastoral systems that do not meet the forest definition. Non-forest land with woody shrubs may be classified as **sparse woodland** to distinguish it from land that is dominated by grass species.

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories.

Wetland includes land that is covered or saturated by water for all or part of the year and that does not fall into the forest land, cropland, grass land or settlements LULC classes. Examples include peat lands, reservoirs, and rivers.

Other land includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories.

The process of dividing land into one of the LULC classes is defined as **LULC classification**, while the process of sub-dividing the forest LULC class into more narrow forest strata is defined as **forest stratification**.

Land transition

Land use or cover changes over time; land transitions from one LULC class or forest stratum into another. This methodology considers four main categories of transitions.

Deforestation (DF), per section 4.2.6.2 of the IPCC GPG-LULUCF 2003, is the process taking place on land the meets the following conditions:

- Meets the definition of forest at the beginning of the historical reference period, or 10 years before project implementation, whichever is earliest.
- Does not meet the definition of forest anymore at some time after the start of the historical reference period (or 10 years before project implementation) as the result of direct human-induced interventions.
- Will not meet the definition of forest within the period of time used to define temporarily un-stocked.

Forest degradation (DG) refers to the gradual loss of carbon on forest land as a consequence of direct human intervention (e.g., logging, fuel-wood collection, or human-induced fire) but still remains forest land. Following the suggested definition of the IPCC (2003b), forest degradation is defined as:

> *A direct, human-induced, long-term (persisting for x years or more) decrease of at least y% of forest carbon stock* [and forest values] *since time t and not qualifying as deforestation.*

The IPCC has not set out any rules to quantify *x*, *y* and *t* at this point.

Forest regeneration (RG) refers to a gradual increase in carbon stock on forest land due to natural succession or human assistance. It is the converse of forest degradation.

Reforestation (RF) is the conversion of non-forest land back to forest land (e.g., from cropland to forest, or grassland to forest). Reforestation is excluded from this methodology as a project activity for generating carbon credits.

However, natural reforestation and regeneration is included in both the baseline and project scenarios.

Other definitions relevant within the scope of this methodology

Timber harvesting for local and domestic use. The extraction of timber wood for direct use within the project area and by the households that are living within the project area, without on-sale of the timber

Commercial timber harvesting. The extraction of timber wood for further sale on local, provincial, national, or international markets outside of the project area or transferred to non-project participants

Participating community. A local community of individuals and households who are permanently living within the project area, are participating in project activities and directly benefit from project activities through increased livelihoods and improved forest resources.

Section I: Summary and Applicability of Baseline & Monitoring Methodology

I.1 Methodology Title and History of Submission

Baseline and Monitoring Methodology for Project Activities that Reduce Emissions from Mosaic-type Deforestation and Increase Regeneration.

This methodology was first submitted on September 12, 2008 to TÜV-SÜD. Corrective action requests were received on December 15, 2008. A revised version was submitted on May 1st, 2009.

I.2 Summary of Methodology

This methodology sets out the project conditions and carbon accounting procedures for activities aimed at reducing unplanned anthropogenic deforestation and forest degradation. The deforestation typology covered by this methodology is of the mosaic type, as defined in the VCS guidance. This methodology explicitly lists the information that is required in a PD so that a third party verifier can validate all *ex-ante* calculations. In addition, it stipulates which information must be included in monitoring reports so that a VCS-accredited verifier can verify these and actual VCUs can be issued.

I.3 Criteria for Applicability of this Methodology

Project proponents must demonstrate that project conditions meet the following list of criteria.

1. Land in the project area has qualified as forest at least 10 years before the project start date (VCS 2007.1, 2008 p 16).
2. The decrease in carbon stored in long-lived wood products due to avoiding illegal logging for timber for commercial on-sale is insignificant. More specifically, the contribution of avoiding illegal timber for commercial on-sale to the total GHG benefits from the project is less than 20%. Logging is defined as commercial-scale when the timber is sold outside of the project area to non-project participants. Assuming a conservative a conservative proportion of harvest logs going into long-term wood products of 30% (a range of 25-29% is reported for Indonesia and Ivory Coast in the Noel Kempff CDM-AR-PDD), and a milling efficiency of 80%, the less than 20% difference in timber would translate into less than 5 % of the total credits. Therefore, long term wood products can be omitted as a carbon pool (VCS 2007.1, 2008 p 19). Use the procedure in section II.4.1 to confirm this criterion.
3. Deforestation and forest degradation in the project area occurs due to one or more of the following categories of drivers
   - Fuel-wood collection or charcoal production
   - Human-induced forest fires
   - Conversion of forest land to crop-land or grazing land

- Conversion of forest land to settlements
- Illegal logging of timber for commercial sale
- Logging of timber for local and domestic use

4. Silvicultural activities to assist natural forest regeneration (ANR) on degraded forest land are allowed as leakage prevention activities (VCS 2007.1, 2008 p 12: "Activities that […] enhance carbon stocks of degraded and/or secondary forests […] are creditable under the VCS according to the guidance provided in this REDD section."). Cumulative credits from silvicultural activities must account for less than 30% of the cumulative credits generated by the project. The ANR management plan, including a detailed description of all activities including their location, must be included in the PD. An update to the management plan may be submitted at the first verification. However, after first verification, the management plan must be fixed.
5. The magnitude of activity-shifting leakage can be quantified through a rigorous monitoring plan consisting of rural appraisals, remote sensing analysis and biomass inventory. The exact procedures for doing so are included in this methodology.
6. To minimize the effects of market leakage, no commercial timber harvesting may be planned in the project areas after the project starts (VCS 2007.1, 2008 p 23 point 23: "leakage caused by market effects is not considered except for cases where timber production is significantly affected."). In addition, no on-sale of fuel-wood gathered or charcoal produced in the project areas is allowed after the project starts.
7. Data on past land use, land cover, and forest cover are available for at least three points in time, spanning a period of 3-15 years before the start of the project activities. Broad LULC classes must be recognized with a minimal accuracy of 90%. If forest degradation is to be included, forest biomass density classes must be recognized with a minimal accuracy of 80%. Note that avoided deforestation credits are discounted based on the accuracy of LULC classification, and credits from avoided forest degradation (if included) based on the accuracy of forest biomass classification.
8. All land areas registered under the CDM or under any other carbon trading scheme (both voluntary and compliance-oriented) must be transparently reported and excluded from the project area. The exclusion of land in the project area from any other carbon trading scheme shall be monitored over time and reported in the monitoring reports.
9. No oil palm plantations or short rotation woody crops are present under the baseline scenario within the project area after deforestation.
10. The following conditions are met so that soil organic carbon can be omitted as a carbon pool (see http://cdm.unfccc.int/EB/033/eb33_repan15.pdf):
    - The project areas shall not include organic soils (e.g., peat-lands), or wetlands
    - Removal of existing vegetation for assisted natural regeneration or fire prevention measures shall not occur on more than 10% of the project area

- Project activities will not remove any fine litter (woody twigs less than 2mm diameter, bark and leaves)

11. If the proposed REDD project activity produces forage to feed livestock, all forage shall have a similar nutritional value and digestibility, and will support only a single livestock group with a single manure management system.

12. If agricultural intensification is proposed as a project activity, it must only occur on land that is already under agricultural use or on land that is to be converted to agriculture in land use plans as part of this project.

I.4 Requirements for Included Gases and Carbon Pools, Geographical Project Boundaries, and Project Duration

I.4.1 Gases

This methodology requires accounting of emissions of all three biogenic greenhouse gases (CO_2, N_2O and CH_4) from sources not related to changes in carbon pools, henceforward referred to as "emission sources" (Table 2). Project proponents may omit certain emission sources, but only if they can prove that their contributions are insignificant. The VCS defines significant sources as those accounting for more than 5% of the total GHG benefits generated (VCS 2007.1, 2008 p 17). As explained in section 0, this methodology uses the procedure outlined in EB31 Appendix 16 (http://cdm.unfccc.int/EB/031/eb31_repan16.pdf) to calculate the significance of emission sources.

Table 2. GHG emissions from sources not related to changes in carbon pools ("emission sources") to be included in the GHG assessment

	Emission Source	Gas	Included?	Justification/Explanation
Emissions from activities within the project area	Boundary poles and fencing	CO_2	Included	Major source
		CH_4	Included	Not existent
		N_2O	Included	Not existent
	Fossil fuel used for vehicles	CO_2	Included	Major source
		CH_4	Excluded	Negligible
		N_2O	Excluded	Negligible
	Loss of biomass due to fire prevention activities	CO_2	Included	Major source
		CH_4	Included	Major when biomass is removed through controlled burning
		N_2O	Included	Major when biomass is removed through controlled burning
Emissions from leakage prevention measures	Increased area of rice production systems	CO_2	Excluded	Not applicable
		CH_4	Included	Major source
		N_2O	Excluded	Not applicable
	Increased fertilizer use	CO_2	Excluded	Not applicable
		CH_4	Excluded	Not applicable
		N_2O	Included	Major source
	Increased emissions from increases in livestock stocking rates	CO_2	Excluded	Not applicable
		CH_4	Included	Major source
		N_2O	Included	Major source
	Changes to manure management related to increased livestock stocking rates	CO_2	Excluded	Not applicable
		CH_4	Included	Major source
		N_2O	Included	Major source
Emissions from assisted natural regeneration	Removal of biomass to prepare assisted natural regeneration	CO_2	Included	Not applicable
		CH_4	Excluded	Major source
		N_2O	Excluded	Major source
	Removal of biomass to prepare assisted natural regeneration by burning	CO_2	Excluded	Not applicable
		CH_4	Excluded	Major source
		N_2O	Included	Major source
	Fertilizer used during enrichment planting for assisting natural regeneration	CO_2	Excluded	Not applicable
		CH_4	Excluded	Not applicable
		N_2O	Included	Major source

I.4.2 Carbon Pools

Table 3 summarizes the carbon pools that must be included in projects following this methodology.

Table 3. Selected Carbon Pools

Carbon Pool	Included?	Justification/ Explanation of Choice
Above-ground tree biomass	Included	Major carbon pool affected by project activities
Above-ground non-tree biomass	Excluded	Expected to decrease under the baseline scenario when no oil palm, or short rotation woody crops are present (applicability criterion).
Below-ground biomass	Included	Major carbon pool affected by project activities
Dead wood	Included	Major carbon pool affected by project activities
Litter	Excluded	Expected to decreases under the baseline scenario when the applicability criterion are met.
Soil organic carbon	Excluded	Expected to decrease under the baseline scenario when the applicability criterion are met
Wood products	Excluded	Under applicability criterion 2, changes in long-lived wood-products are less than 5%, and can be omitted.

I.4.3 Spatial Boundaries

The spatial boundaries of (1) the project area, (2) the leakage area and (3) the reference region must be unambiguously defined in the PD. The project area may be contiguous or consist of multiple adjacent or non-adjacent parcels, "discrete project area parcels". Around each discrete project area parcel, a leakage belt shall be defined. Before the start of the project, the reference region must include the project area and leakage area. After the start of the project, the reference region may not contain the project area and leakage belt.

I.4.4 Project Duration

Project duration is fixed and must minimally 20 years, and maximally 100 years (VCS 2007.1, 2008 p 17).

Reporting requirements in the PD	PD Section
1. Evidence that each of the applicability conditions are met.	2.2
2. A list of specific sources of greenhouse gases that will be considered in the project based on Table 2.	2.3

I.5 Summary of Major Methodological Steps for the Baseline GHG Emissions, Project GHG Emissions, and Monitoring

The annual net GHG emission reductions due to project activities (NERs) must be estimated *ex-ante* in the PD using Equation (1). In addition, the PD must contain an estimate of the *ex-ante* VCUs that are issued after transferring a portion of the NERs to the buffer pool according to the buffer withholding percentage (VCS 2007.1, 2008 p 22). The actual NERs and VCUs are calculated *ex-post* based on data collected during monitoring. The calculation of actual NERs and VCUs is included in a monitoring report. The VCS will only release actual VCUs after verification of the monitoring report by a

VCS-accredited verifier taking into account the buffer withholding percentage. The calculation of emission reductions is based on the following principles:

- This methodology separates emission reductions from avoided deforestation, emission reductions from avoided forest degradation, and carbon update through assisted natural regeneration.
- Emission reductions from avoided deforestation (DF) are separated from emission reductions from avoided degradation (DG) because different accuracy thresholds and discounting procedures are imposed for deforestation and forest degradation. If the accuracy threshold for analyzing forest degradation is not met, only credits from avoided deforestation can be generated. However, if sufficient data becomes available during the crediting period, credits from avoided degradation may be included during the crediting period.
- The calculation of NERs within this methodology is based on a classification and stratification of the land in discrete classes or forest strata according to the land use and land cover (LULC) or forest type and density. By analyzing a transition from one class or stratum to a different class or stratum, deforestation and forest degradation can be quantified. Deforestation is a transition from a forest class to a non-forest class. Forest degradation is a transition of a forest stratum to a forest stratum with a lower biomass.
- Emission reductions from avoided deforestation or degradation are calculated by multiplying the size of the area on which the transition was averted, i.e. the activity data, by the emission factor related to this transition. The emission factor is the difference in carbon stocks between the "from" and "to" states of the transition. The size of the transition areas is estimated using a combination of remote sensing analysis and computer modeling, whereas the emission factors are quantified using a biomass inventory.
- All NERs must be discounted for conservativeness using a discounting factor for the uncertainty of the classification, $u_{classification}$ and a discounting factor for the uncertainty of the biomass inventory$\cdot$ $u_{inventory}(i)$.
- Greenhouse gas benefits from assisted natural regeneration (ANR) activities are calculated using the approved consolidated CDM methodology AR-ACM0001 version 3: "Afforestation and Reforestation of Degraded Land".
- Significant methane, nitrous oxide and fuel-CO_2 emissions from project and leakage prevention activities must be subtracted from the NERs. The significance of each of these emissions is tested according to the methodology provided in EB31 appendix 16 to determine whether it must be included (see section II.4.1).

The PD must include an estimate of the net emission reductions calculated for every year t of the crediting period. Equation (1) on the following page is used to calculate annual net emission reductions (NERs).

The procedure to calculate *ex-ante* NERs consists of three major parts: (1) calculation of the baseline scenario, (2) calculation of the project scenario and (3) estimation of leakage. The following section provides an overview of each of the individual parts. During the crediting period, all project actions and conditions in the project area must be monitored. A brief summary of monitoring is included in the following section.

$$
NERs(t) = \begin{pmatrix}
+\sum_{i=1}^{nrFNFtransitions} \left(u_{classification} \cdot \begin{pmatrix} +\Delta area_{projectAreaWithoutANR,projectScenario}(t,i) \\ -\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i) \end{pmatrix} \cdot u_{inventory}(i) \cdot EF(i) \right) & [1] \\
+\sum_{i=1}^{nrFNFtransitions} \left(u_{classification} \cdot \begin{pmatrix} +\Delta area_{leakageArea,projectScenario}(t,i) \\ -\Delta area_{leakageArea,baselineScenario}(t,i) \end{pmatrix} \cdot u_{inventory}(i) \cdot EF(i) \right) & [2] \\
+\sum_{i=1}^{nrStrataTransitions} \left(u_{stratification} \cdot \begin{pmatrix} +\Delta area_{projectAreaWithoutANR,projectScenario}(t,i) \\ -\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i) \end{pmatrix} \cdot u_{inventory}(i) \cdot EF(i) \right) & [3] \\
+\sum_{i=1}^{nrStrataTransitions} \left(u_{stratification} \cdot \begin{pmatrix} +\Delta area_{leakageArea,projectScenario}(t,i) \\ -\Delta area_{leakageArea,baselineScenario}(t,i) \end{pmatrix} \cdot u_{inventory}(i) \cdot EF(i) \right) & [4] \\
+GHG_{otherLeakageSources}(t) & [5] \\
+\frac{44}{12} \sum_{i=1}^{nrStrata} \Delta C(t,i) - \begin{pmatrix} +\frac{44}{12} \cdot CF \cdot \sum_{i=1}^{nrStrata} NAI(i) \cdot area_{projectAreaWithANR,baselineScenario}(t,i) \\ +\sum_{i=1}^{nrFNFtransitions} \left(u_{classification} \cdot \Delta area_{projectAreaWithANR,baselineScenario}(t,i) \cdot u_{inventory}(i) \cdot EF(i) \right) \end{pmatrix} & [6] \\
-E_{sources,projectArea}(t) - E_{sources,leakagePrevention}(t) - E_{sources,ANR}(t) & [7]
\end{pmatrix} \quad (1)
$$

[1] = GHG benefits related to avoided deforestation (DF).

[2] = GHG emissions from deforestation due to leakage. Values are negative.

[3] = GHG benefits related to avoided degradation (DG). If emission reductions from avoided degradation were excluded due to insufficient accuracy, in which case $u_{stratification} = 0$, emission reductions from fuel-efficient woodstoves may still be included, see section II.4.2.

[4] = GHG emissions from degradation due to leakage.

[5] = GHG emissions from leakage due to unconstrained geographic drivers and market leakage.

[6] = Net GHG benefits related to assisted natural regeneration (ANR) in forests

[7] = Emissions from methane, nitrous oxide, and fuel due to project activities and assisted natural regeneration.

Variable	Explanation	Section
$NERs(t)$	Net emission reductions during year t.	II.4.4
$nrFNFtransitions$	Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the "from" or the "to" class are non-forests.	II.1.2.3
$nrStrataTransitions$	Number of transitions among forest strata.	II.1.2.3
$nrStrata$	Number of strata within the ANR area.	II.1.2.3
$\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$	Hectares undergoing transition i within the project area, excluding the ANR area, under the project scenario for year t. [ha yr^{-1}] This quantity is estimated *ex-ante*, but monitored during project execution and verified *ex-post* before issuance of VCUs.	II.2.2
$\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$	Hectares undergoing transition i within the project area, excluding the ANR area, under the baseline scenario for year t. [ha yr^{-1}] This quantity is verified *ex-ante* and remains fixed until the baseline is updated, which must be done at least every ten years, as specified in the PD. The issuance of *ex-post* VCUs is based on these *ex-ante* determined baseline emissions.	II.1.5.4
$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$	Hectares undergoing transition i within the ANR area under the baseline scenario for year t. [ha yr^{-1}] This quantity is verified *ex-ante* and remains fixed until the baseline is updated, which must be done at least every ten years, as specified in the PD. The issuance of *ex-post* VCUs is based on these *ex-ante* determined baseline emissions.	II.2.4.1
$\Delta area_{leakageArea,projectScenario}(t,i)$	Hectares undergoing transition i within the leakage area under the project scenario for year t. [ha yr^{-1}] This quantity is estimated *ex-ante*, but monitored during project execution and verified *ex-post* before issuance of VCUs.	II.3.2.3

Variable	Explanation	Section
$\Delta area_{leakageArea,baselineScenario}(t,i)$	Hectares undergoing transition i within the leakage area under the baseline scenario during year t. [ha yr^{-1}] This quantity is verified *ex-ante* and remains fixed until the baseline is updated, which must be done at least every ten years, as specified in the PD. The issuance of *ex-post* VCUs is based on these *ex-ante* determined baseline emissions.	II.1.5.4
$\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$	The size of the area within the project area where no assisted natural regeneration (ANR) activities are planned of transition i during year t. [ha yr^{-1}] This quantity is estimated *ex-ante*, but monitored during project execution and verified *ex-post* before issuance of VCUs.	II.2.2
$EF(i)$	Emission Factor for transition i.	II.1.4.6
CF	Carbon fraction of wood (use 0.5 by default).	
$NAI(i)$	Net annual increment on the initial class of transition i.	II.1.4.2
$area_{projectAreaWithANR,baselineScenario}(t,i)$	Size of strata i within the project area on which ANR activities are proposed for year t under the baseline scenario.	II.2.4.1
$u_{stratification}$	Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes.	II.1.2.4.3
$u_{classification}$	Discounting factor for NERs from avoided deforestation, based on the accuracy of classification, i.e. dividing land into broad land use types.	II.1.2.4.3
$u_{inventory}(i)$	Discounting factor for all emission reductions, based on the uncertainty of biomass inventory related to transition i.	II.1.4.6.1
$\Delta C(t,i)$	Annual change in carbon stock in all selected carbon pools for forest stratum i and year t.	II.2.4.1
$E_{sources,projectArea}(t)$	Emissions from sources of methane, nitrous oxide or fuel-CO_2 from activities within the project area for year t. This quantity is estimated *ex-ante*, but monitored during project execution and verified *ex-post* before issuance of VCUs.	II.2.3

Variable	Explanation	Section
$E_{sources,leakagePrevention}(t)$	Emissions from sources of methane, nitrous oxide or fuel-CO_2 from leakage prevention activities for year t. Emission sources within the leakage area are included in Table 2. This quantity is estimated *ex-ante*, but monitored during project execution and verified *ex-post* before issuance of VCUs.	II.3.4
$E_{sources,ANR}(t)$	Emissions of sources of methane, nitrous oxide or fuel-CO_2 from assisted natural regeneration activities for year t.	II.2.4.3

VCUs are then calculated by discounting the NERs according to the buffer withholding percentage as determined using the VCS's tool for AFOLU non-permanence risk analysis and buffer determination.

$$VCUs(t) = (1 - buffer) \cdot NERs(t) \tag{2}$$

where:

$VCUs(t)$	=	Voluntary Carbon Units. [MTCO2e]
$buffer$	=	the buffer withholding percentage according to the VCS's tool for AFOLU non-permanence risk analysis and buffer determination. [-]
$NERs(t)$	=	Net Emission Reductions. [MTCO2e]

I.5.1 GHG Sinks and Emissions under the Baseline Scenario

Under this methodology, the most plausible baseline scenario under the CDM modalities and procedures, paragraph 22 is option (a) (see section II.1). The calculation of the deforestation in the project area under the baseline scenario is based on a combination of remote sensing analysis of historical images and land-use change modeling. First, the total rate of deforestation and forest degradation in the project area is estimated based on the empirical land-use and forest cover changes in a reference region similar to the project area. Subsequently, a simple land use change model is used to divide the total rate into individual rates for every forest stratum. The procedure to calculate the baseline deforestation and forest degradation rates for every land class and forest stratum in the project area is summarized in Figure 1 and explained in detail in section II.1. The calculation of the baseline deforestation and forest degradation rates in the leakage area follows a similar methodology and is completed once the size of the leakage area is determined, which is explained in section II.3.2.2.

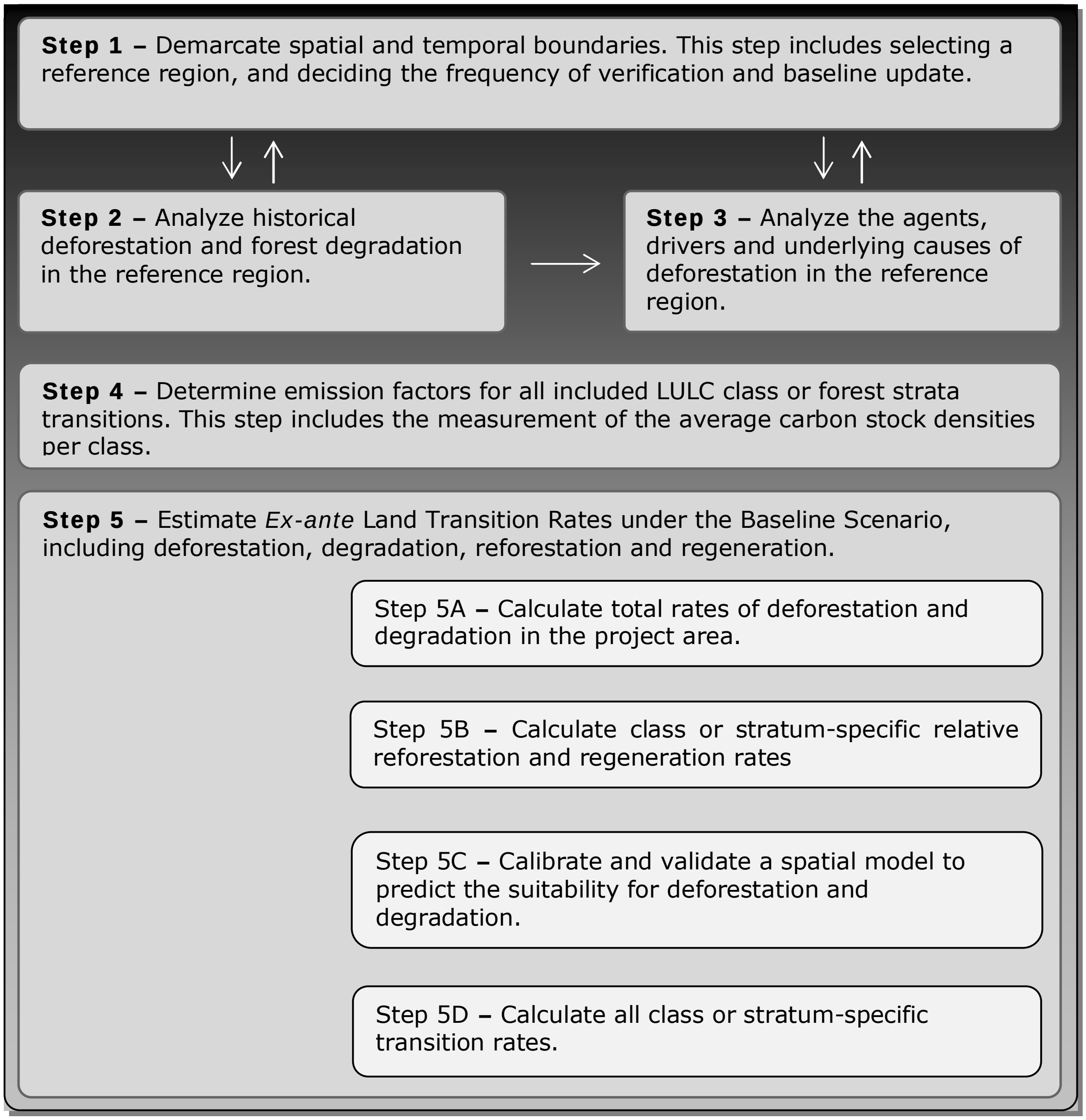

Figure 1. Baseline Scenario: major steps required to calculate GHG emissions under the baseline scenario

I.5.2 GHG Emissions and Sinks under the Project Scenario in the Project Area

The methodology for the *ex-ante* calculation of the greenhouse gas emissions inside the project area under the project scenario is outlined in Figure 2. The relative reduction in deforestation rates is calculated by aggregating the *ex-ante* expected effect of a project activity on each driver (Step 6). The simple spatial model calibrated previously is then used to divide the total deforestation and forest degradation rates in the project scenario into forest-strata specific rates (Step 7). Subsequently, emission sources from project activities are calculated. In a last step, GHG sinks from assisted natural regeneration activities are calculated based on the approved CDM technology AR-ACM0001 version 3. A detailed procedure for each of these steps can be found section II.2.

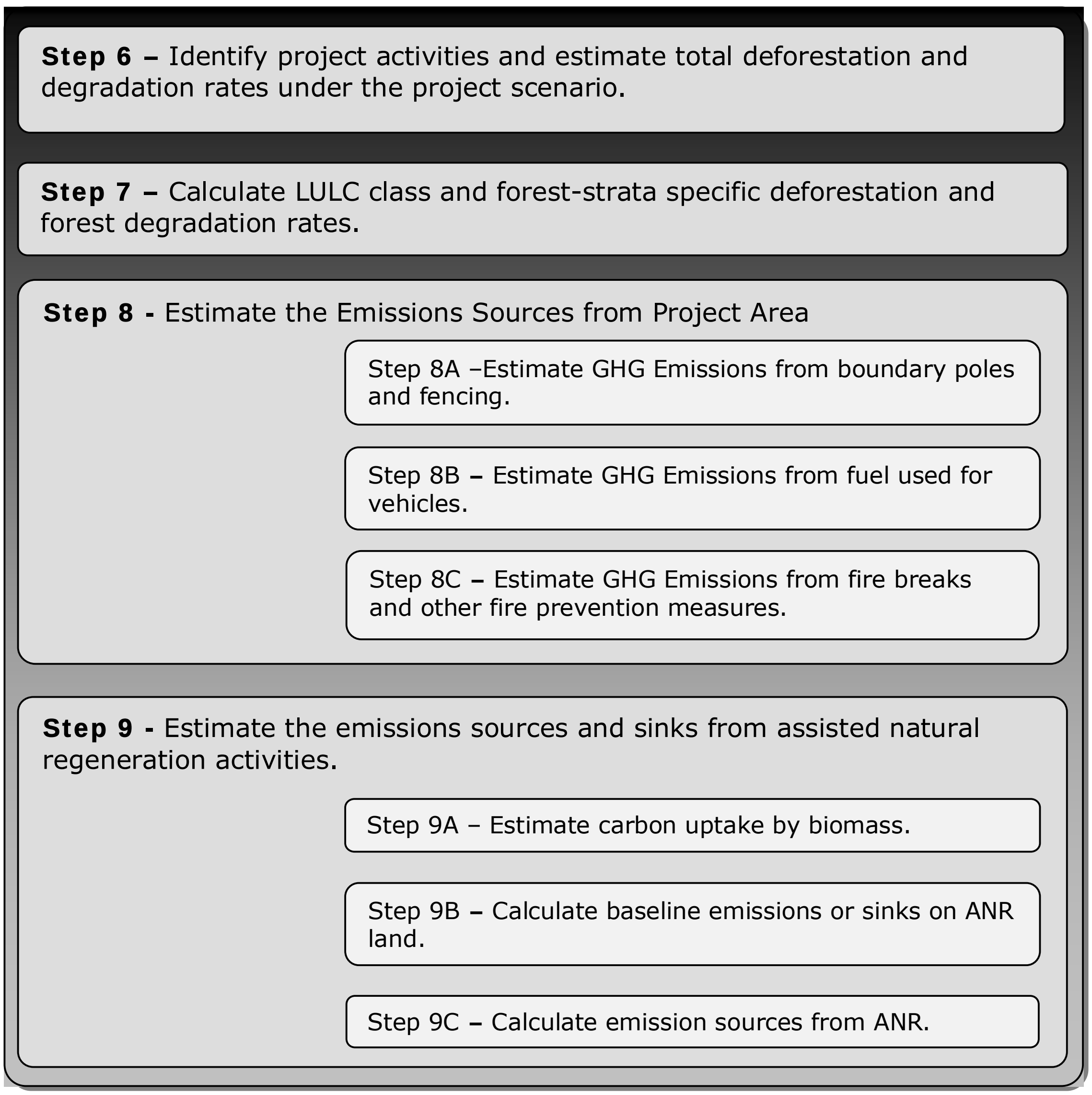

Figure 2. Project Scenario: Steps required to calculate GHG emissions inside of the project area under the project scenario.

I.5.3 GHG Emissions under the Project Scenario outside the Project Area (Leakage)

Under this methodology, leakage is calculated separately for every individual project action. GHG emissions due to primary leakage through activity-shifting attributable to the project activity must be accounted for under VCS 2007.1, 2008 p 23 point 23. This methodology assumes (1) that the amount of leakage can be estimated before project implementation, (2) that activity-shifting leakage related to drivers that are geographically constrained, e.g. forest fires, collection of fuel-wood, grazing and the production of charcoal are restricted to a geographical region around the discrete project area parcels, called the leakage belt, (3) that the location and the size of the leakage belts can be identified during before the start of the project and (4) that the activity-shifting leakage related to activities that target drivers that are geographically unconstrained, e.g. illegal commercial timber harvesting, and market leakage can be conservatively estimated using a factor approach. Note that the methodology excludes commercial timber harvesting in the project area after project start through the applicability criteria.

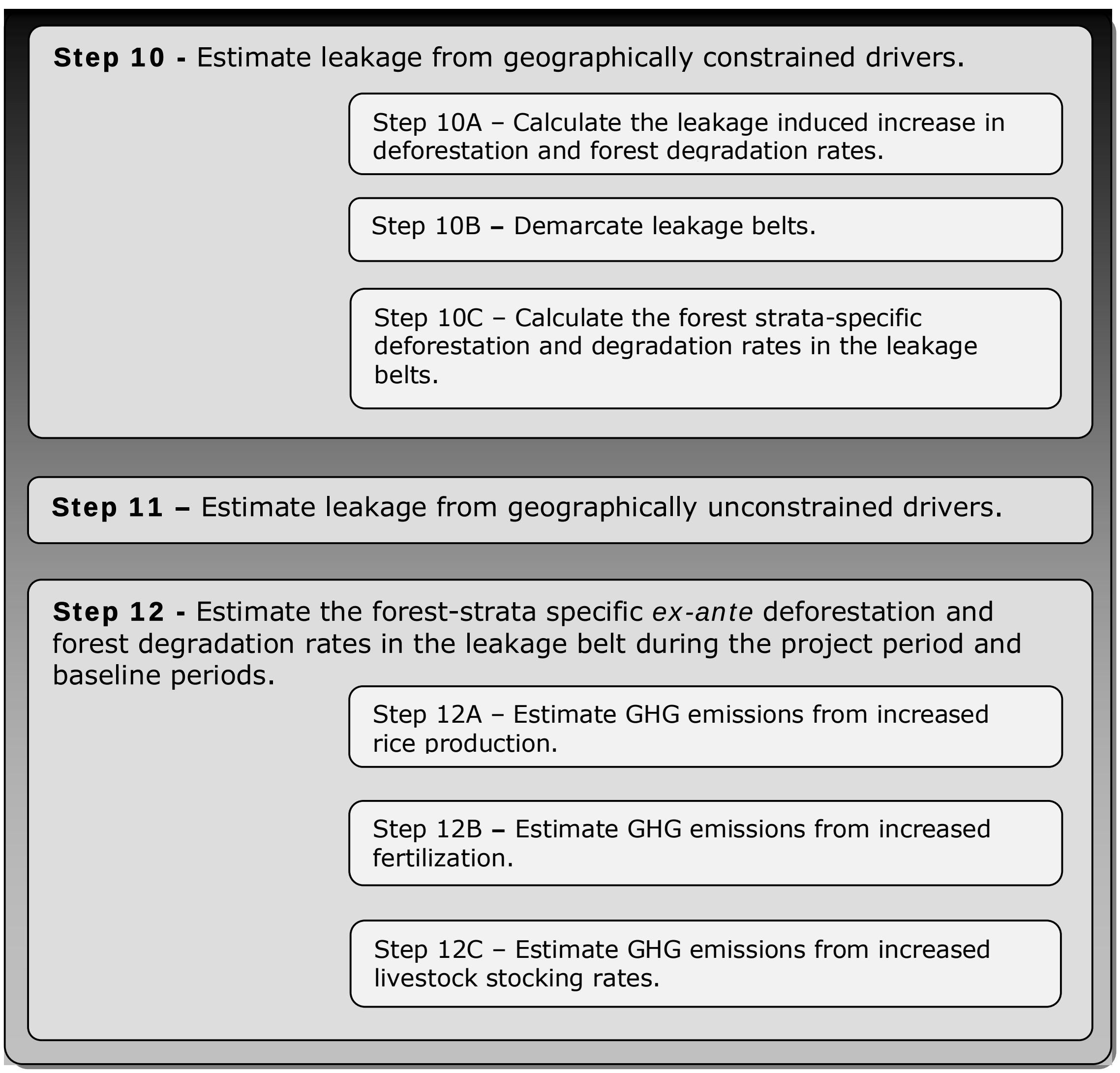

Figure 3. Leakage: Steps required to calculate GHG emissions outside of the project area under the project scenario.

I.5.4 Calculate *Ex-ante* NERs

Once the individual steps above are performed, the significance of the different emission sources can be tested. Only the significant emissions need to be retained in the final calculations. All calculated values are brought together and the net *ex-ante* NERs are calculated using Equation (1). By applying the buffer withholding percentage, VCUs can be calculated using Equation (2).

I.5.5 Monitoring Methodology

During the crediting period, the monitoring variables must be recorded with the frequency specified in the PD. For verification, project proponents must compile all monitored data in a monitoring report and submit the monitoring report to a VCS verifier. A positive evaluation will allow VCUs to be issued by the VCS. Monitoring has three components: (1) estimating transitions of LULC classes and forest strata, (2) measuring carbon stock densities per LULC class using field sampling techniques and (3) tracking all GHG emissions from emission sources.

- Changes in land and forest cover are monitored using a combination of remote sensing analysis and ground-truthing data. During the crediting period, project proponents must conduct regular mapping analysis in the project area, reference region, and leakage area to monitor deforestation and forest degradation rates in these areas.
- Carbon stock densities from the land and forest classes must be regularly updated by conducting a biomass inventory.
- All changes in GHG emissions that are not related to carbon pools and that are directly attributable to project activities, must be recorded. These include fuel CO_2 emissions due to patrolling of the forest, increased N_2O and CH_4 emissions from greater fertilizer use related to agricultural intensification, intensification of livestock management, and associated manure management. The quantification of the emission sources is done by duly recording all project activities and inputs and by conducting interviews or social appraisals.

Section II: Description of the Methodology for *Ex-ante* Estimation of NERs and Additionality

II.1 *Ex-ante* Estimation of GHG Emissions and Changes in Sinks under the Baseline Scenario

Under this methodology, the most plausible baseline scenario under the CDM modalities and procedures, paragraph 22, option (a):

> *Existing or historical, as applicable, changes in carbon stocks in the carbon pools within the project boundary.*

Option (a) is selected because under the mosaic typology of deforestation, the historical changes in land-use are representative for the most likely future changes in land-use. The most appropriate future scenario is that historical rates and dynamics of deforestation and forest degradation will continue in the future. No new economically attractive course of action is expected in the future, therefore option (a) was selected, and not option (b).

The selected baseline shall be in compliance with all mandatory applicable legal and regulatory requirements, even if these laws and regulations have objectives other than GHG reductions, e.g. to mitigate local air pollution (EB 29, Annex 5).

The net GHG sources and sinks under the baseline scenario must be estimated *ex-ante* for each year of the crediting period. Once validated, the baseline is to be used for the calculation of actual NERs during a baseline validation period. Baseline calculations remain valid only for a limited period of time and must be updated based on new observations of land use change in the reference region. In this way, baselines incorporate the effect that changes in national and local policies and circumstances that influence the land use decisions of deforestation agents. Following the VCS AFOLU guidance, baselines must be updated at least once every ten years (VCS 2007.1, 2008). The times of baseline updates must be fixed and included in the PD (see section II.1.1.3). The updated baseline must be submitted and validated by a VCS verifier during a verification event.

II.1.1 Step 1 – Select Spatial and Temporal Boundaries

This step includes the demarcation the project area and the reference region. Note that the demarcation of the leakage area is included in section II.3.2.2.

II.1.1.1 Step 1A – Describe Spatial Boundaries of the Discrete Project Area Parcels

Project proponents shall provide digital (vector-based) files of the discrete project area parcels in a common GIS software format. A clear description must accompany each file, and the metadata must contain all necessary projection reference data. In addition, as per VCS 2007.1, 2008 p 17, the PD must include a table containing the **name** of each discrete project area parcel , the **centroid coordinate** (latitude and longitude using a WGS1984 datum), the **total land area** in ha, **details of tenure/ ownership** and the relevant **administrative unit** belongs to (county, province, municipality, prefecture, etc.).

Following VCS 2007.1, 2008 p16-17, new discrete project area parcels (referred to as "new project area") may be integrated into an existing project with some limitation. Adding new project area parcels can occur only once and must be included in the monitoring report for the first verification. After the first verification, the geographical boundaries of the project area and the specific discrete project parcels are fixed for the rest of the crediting period. The addition of new project areas can only occur upon a positive evaluation of the relevant section in the monitoring report (see III.3.1) by a VCS-accredited verifier. Section III.3.1 contains the criteria that must be met before new project area can be added.

II.1.1.2 Step 1B – Select Size and Location of the Reference Region

Existing regional or national baselines that are spatially explicit and approved by the competent national authority must be adopted if they provide an equally or more accurate measure of the project's baseline compared to this methodology. If no such applicable regional or national baseline is available, a stratified regional baseline (Sathaye and Andrasko, 2007; Brown et al., 2008) must be developed in a reference region around the project area. The reference region typically consists of a watershed, a province or state, or sometimes the entire country. Information about deforestation agents and drivers and the rate of deforestation and forest degradation is calculated from the reference region that is larger than the project area, and is used as a proxy for the baseline calculations within the project area. Note that before the project start date, i.e. during the historical reference period, the reference region must include the project and leakage areas. However, after project start, the reference region may not include the project and leakage areas anymore.

Size of Reference Region. The minimum size of the reference region is dependent on the size of the project area. Project proponents must use Table 4 to determine the minimal size of the reference region.

Table 4. Requirements for the minimal size of the reference region, relative to the size of the project area.

Size of the Project Area (ha)	Minimal size of the Reference Region relative to the Project Area (number of times larger)
< 25,000	20 ×
25,000 – 50,000	10 ×
50,000 – 100,000	5 ×
> 100,000	2 ×

The conditions in the discrete project area parcels must be similar to the conditions in the reference region (see below). A larger reference region is not necessarily more conservative. For example, if encroaching by migrants is the main deforestation driver in the project area, and the reference region is expanded to an area where land tenure enforcement prohibits encroachment, deforestation rates based on the total reference region will be underestimated. Use the following procedure to fix the location of the reference region.

Location of Reference Region. The reference region must exclude all areas on which the access by agents of deforestation is restricted, such as national parks, army bases, or land concessions. In addition, the project proponents must demonstrate that the reference region is similar to the project area with respect to a number of key variables, detailed in Table 5.

Sub-Step 1: Demonstrate that the reference region does not contain areas where agents of deforestation have restricted access.

Include maps where the reference region and the project area have been overlaid with maps of protected areas, including:

- National parks that are effectively protected
- Areas under conservation that are effectively protected
- Areas under a logging or economic land concession where access is effectively being restricted
- Large plantations that are effectively protected

Sub-Step 2: Demonstrate the similarity between project area and reference region.

The procedure to compare reference region and project area follows VSC 2007.1, 2008 p 20. Compare the value of every key variable listed in Table 5 between reference region and project area according to the comparison procedure in Table 5. Areas in the potential reference region where one or more of these variables differ from the project area must be excluded. Once these areas are excluded, the homogeneity must be re-evaluated. Therefore, determining the spatial boundaries of the reference region is an iterative process.

Table 5. Comparison variables to demonstrate similarity between project area and reference region and CAR 25.

Category	Variable	Comparison procedure	Explanation
Drivers of deforestation	Evidence of presence of deforestation agents	All agents that were identified in the project area must be present in the reference region	Since the reference area will be used to determine baseline deforestation and degradation rates in the project area, the deforestation drivers must be similar in the reference area and the project area.
Landscape configuration	Distribution of native forest types	The proportion of each forest class of the reference region must be within 10% from the proportion of this class in the project area.	Deforestation and land-use change dynamics are highly dependent on geographical conditions. For example, if the project is to protect a mountain forest on the top of a watershed then low-land humid forests or dry forests on the planes at the bottom of the valley should not be used as a reference region.
	Average Elevation	Average elevation of the reference region shall be within 10% of the elevation of the project area.	
	Average Slope	Average slope of the reference region shall be within 10% of the average slope of the project area.	
	Relative area with slope > 2%	Relative area with slope > 2% in the reference region shall be within 10% of the relative area with slope > 2% in the project area.	
Socio-economic and cultural conditions	Land-tenure status	Demonstrate that the land-tenure system prevalent in the reference region is identical to the land-tenure system in the project area through peer-reviewed literature, reports, or expert's opinion.	The specific land tenure system impacts the rate of land use changes, and must therefore be similar between the project area and reference area.
	Enforced policies and regulations	The reference region should be governed by an administrative unit that has comparable policies, regulations and capacities as the administrative unit of the project area.	Different governing bodies may have a different legislative framework or capacity for enforcement. It has to be demonstrated that the forest is similar in the reference region and project area.
	Proportion of population that is agricultural-based vs. urbanized	Proportion of agriculture-based vs. urbanized population within the reference region shall be within 10% of this proportion in the project area.	People living in urban areas have a significantly different relation to forest land compared to people that are agriculture-based.

II.1.1.3 Step 1C – Specify Temporal Boundaries of the Project

Project proponents must decide the following temporal boundaries

- The **historical reference period** with exact start date. The end of the historical reference period must coincide with the project start date. The duration of the historical reference period must be between 3 and 15 years.
- The **project crediting period** with exact start date and project end date. The start of the crediting period is equal to the start of project date and is the date when the first project activity for which NERs are claimed is implemented. The duration of the crediting period is between 20 and 100 years.
- Project proponents must seek third-party verification at least every five years. The **frequency of verification** may change during the crediting period (e.g., every two years during the first ten years of the crediting period, and every five years thereafter). The exact frequency of verification must be fixed *ex-ante* and specify the exact times (years) during the crediting period when verification will occur.
- **Baselines must be updated** at least every ten years. However, a more frequent update of the baseline must occur when:
  - It is expected that new national, local and sectoral policies are in effect that may influence land use changes.
  - There is a high risk for natural disturbances and catastrophic events (major crown fire, pests, tsunami, earthquake, volcanic eruption, landslide, flooding, etc.).
  - Gradual changes in the carbon stocks due to global climate change, or a change in local environmental conditions are present. Examples are an expected increase in fire incidence due to a decrease in rainfall or an increase in the length of the dry period, or a slow change in the hydrology of the whole region.
  - It is expected that significant changes of political, social or economic nature will occur, making previous baseline estimates inaccurate.
  - The risk that alternative land uses on the land become much more attractive than the REDD project due to market effects such as a significant price rising of timber and non-woody products, or the increase of prices of agricultural commodities would increase the deforestation pressure on the current forest land.

  Baseline updates must coincide with a verification event. The updated baseline must be included in the monitoring report when it is submitted to the VCS-accredited verifier. The **frequency of baseline updates** must be fixed *ex-ante*; the times (years) during the crediting period when the baseline will be updated must be included in the PD.

Reporting Requirements in the PD	PD section
1. Maps for all project areas with the LULC classes and forest stratification.	1.5
2. Shape files of the discrete project area parcels and the reference region. All necessary meta-data to correctly display the files must be included.	Supply electronically
3. Table of all the discrete project area parcels with their ID, name, coordinate centroid (latitude and longitude using a WGS1984 datum), total land area in ha, details of tenure/ownership, and the relevant administrative unit.	1.5
4. Overview map of the whole reference region with the location of the discrete project area parcels clearly indicated.	1.5
5. Evidence that areas with effective protection were excluded from the reference region, such as maps with the location of national parks or economic land concessions.	1.5
6. The size of the reference region relative to the size of the project area for comparison with the relative sizes in Table 4.	1.5
7. Demonstration of the similarity between reference region and project area based on the formal comparison of as listed in Table 5.	1.5
8. Description of the temporal boundaries: start and end of the historical reference period, start and end of the project crediting period, years during the crediting period when verification will be sought, and years during the crediting period when the baseline will be updated.	1.5

II.1.2 Step 2 – Analyze Historical Deforestation and Forest Degradation in the Reference Region

II.1.2.1 Step 2A – Describe Data Sources

The quantification of deforestation and forest degradation rates under this methodology is based in part on remote sensing and other spatial data. The selection of data sources must follow Chapter 3A.2.4 of the IPCC 2006 GL AFOLU and Brown et al. (2007), section 3.2.4. Table 6 lists the data that are minimally required, and the data that are strongly advised. This table also outlines the information about these data that must be documented in the PD. At least three maps of forest cover are required during the historical reference period, a period of 3-15 years before the start of the crediting period: (1) one map at the start of the historical reference period, (2) at least one map during the historical reference period, and (3) one map within one year of the start of the crediting period.

Table 6. Information to be reported on the employed remote sensing and other spatial data.

Data Source Required	Information Needed about the Data Collected
High to medium resolution (< 30 m) **remote sensing data** for at least three time points: (1) one point at the beginning of the historical reference period, 3-15 years before the start of the crediting period,(2) at least one point during the historical reference period, and (3) one point within one year of the start of the crediting period.	• Source • Type • Resolution (spatial and spectral) • Acquisition date • Coordinate system and pre-processing • If different sources of remote sensing data are used, a formal comparison of the sensors should be added to the monitoring report to ensure consistency.
All readily available **LULC maps which are already processed** and interpreted.	• Minimum Mapping Unit (ha) • Description of method used to produce these data • Descriptions of the LULC classes and/or LULC-change categories • Information on how these classes may match with IPCC classes and categories
Recent (< 5 yr) **high resolution** (< 5 m) **remote sensing data** for at least part of the reference region at a time point coinciding with one of the medium-resolution remote sensing images.	• Source • Type • Resolution (spatial, spectral) • Acquisition date • Coordinate system and pre-processing
Direct field observations or visually interpreted locations from remote sensing images for calibration of the classification and stratification procedures and validation of the calibration and classification accuracy.	• Acquisition date • Type of data (classification system used) • coordinate system

II.1.2.2 Step 2B – Define LULC Classes and Forest Strata

The ultimate goal of a correct classification and stratification system is to divide the reference region into LULC classes or forest strata that have homogeneous carbon stock density in a cost-effective and practically feasible way. The LULC class or forest stratum represents the current *state* of the land; it does not reflect the future evolution of the land. The exact number and type of LULC classes and forest strata used is project-specific and dependent on local conditions. A number of iterations between the remote sensing image analysis and the LULC class and forest strata definitions may be necessary before an optimal system can be fixed.

- For the **LULC classification**, include *at least* the six IPCC LULC classes (Forest Land, Crop Land, Grass Land, Wetlands, Settlements, and Other Land). The definition of these classes must be consistent with Chapter 2 of the IPCC GPG-LULUCF 2003. In cases where the country has defined more specific LULC classes than the IPCC classes, these definitions must be used if they are accurate enough for project-specific classification.

- To achieve the goal of defining classes that are homogeneous in carbon stock density, the forest LULC class may be sub-divided into **forest strata**. Forest land is usually heterogeneous in terms of micro-climate, soil condition, forest canopy cover, and forest type. Forest strata are more narrow classes with more or less homogeneous characteristics that have a relatively narrow range in carbon stock density. Stratification of the project area into relatively homogeneous units can either increase the measuring precision without increasing the cost, or reduce the cost without reducing measuring precision because of the lower variance within each homogeneous unit. Increasing the number of classes will lead to a more accurate accounting of the forest carbon. Because emission reductions are discounted based on the uncertainty of biomass inventory, increasing the number of classes will lead to a greater amount of emission reductions. However, a larger number of forest strata will likely also increase costs, as it requires more input data and analysis time.

  The forest stratification is implemented using the following steps.

  Step 1: Assess the key factors that influence carbon stocks in the above- and below-biomass pools within the reference region. These factors should include soil features, micro-climate, landform (e.g., elevation, slope, and aspect), forest type and dominant tree species and project actions

  Step 2: Collect maps of key factors identified in step 1 within the reference region, including:
  - Micro-climate maps if significant climatic differences exist
  - Native forest type (such as evergreen, deciduous, broadleaved, mangrove, or coniferous)
  - Forest canopy cover maps (e.g., <20%, 20-40%,40-70%, >70%) based on the satellite image analysis (see below)
  - Soil types, parent rocks and preferably soil maps
  - Landform information and/or maps
  - Soil erosions intensity map
  - Forest management (e.g., age or time since last harvest)
  - Human degradation intensity (e.g., distance to roads and distance to settlements)
  - Other information relevant to key factors identified above. **Forest plantations or commercial timber concessions** must be classified using their average carbon density over a rotation cycle.

  Data sources may include archives, records, statistics, study reports and publications of national, regional or local governments, institutes and/or agencies, and literature. Develop a stratification system as depicted in Figure 4.

  Step 3: Preliminary stratification. The stratification shall be conducted by re-classifying the maps collected in step 2 into LULC classes and forest strata that have significant differences in carbon stock density. For example a raster map of slopes could be classified into four slope classes: <5 degrees, 5-10 degrees, 10-20 degrees, >20 degrees. A GIS platform must be used to overlay the re-classified maps.

  Step 4: Field survey. Conduct a biomass inventory on at least three plots for each preliminarily identified stratum. In each plot, record tree species, crown cover, and mean diameter at breast height (DBH) for every tree in the plot, and record the forest type of the plot.

Step 5: Final stratification. With the information from the field survey, evaluate the homogeneity of the carbon stock densities within each preliminary forest stratum. If necessary, adjust the stratification procedure to minimize the stratum heterogeneity, while including differences in management or degradation pressure. A stratum within which there is a significant variation in any of vegetation type, soils and project actions must be divided into two or more strata. On the other hand, strata with similar features shall be merged into one stratum. Distinct strata should differ significantly from each other in terms of how they impact the baseline and/or project carbon stock. For example, sites with different species and age classes of trees shall form a separate stratum. Sites with a more intensive collection of fuelwood might also be a separate stratum. On the other hand, site and soil factors may not warrant a separate stratum as long as all lands have a baseline of continued degradation, with little to no vegetation growing, and with no human intervention, and as long as the carbon accumulation in above-ground and below-ground biomass is similar in the project scenario.

Native Forest Type
- Evergreen
  - Dense and inaccessible evergreen forests
  - Evergreen forest with some evidence of illegal logging
  - Highly logged and accessible evergreen forests
- Mixed
  - Dense and inaccessible mixed forest
  - Mixed forest with medium density and poor soil conditions
  - Highly degraded and accessible mixed forests
- Deciduous
  - Deciduous forests with intermediate biomass density
  - Deciduous forests with low biomass density and high degradation pressure

Figure 4. Example of a forest stratification system.

Note that this forest stratification reflects the current *condition or state*, and not the *process* of change or future *evolution* of the specific forest class. A degraded forest class will regenerate if the deforestation drivers are removed. In contrast, a low-density open forest might stay in a low-carbon state due to an impermeable clay layer in the soil, impeding root growth. Although their future evolution will be completely different, these two forest systems might both be in the low-carbon density forest class.

- In addition, all **areas that will be subject to ANR activities** must be further divided into forest strata according to the specific silvicultural management activities that will be employed on these areas. *Ex-post* adjustment of the stratification according to ANR activities is allowed until the first verification.

(a) Gather information on variables that influence biomass growth potential. These factors may include soil, climate, previous land use, existing vegetation type, degree of anthropogenic pressure in the baseline scenario, etc.

(b) Define the stand models to be implemented in the project area by specifying:

- The species or species combination to be planted together in one single location and at the same date to create a so-called stand model
- The growth assumptions for each species or combination of species in the stand model
- Planting, fertilization, thinning, harvesting, protecting, coppicing, and replanting cycle scheduled for each stand model, by specifying:
    - The age class when the above management activities will be implemented
    - The quantities and types of fertilizers to be applied
    - The volumes to be thinned or harvested
    - The volumes to be left on site (harvest residues becoming dead wood) or extracted

(c) Define the establishment timing of each stand model by specifying:

- The planting date
- The area to be planted (ha)
- The geographical location for each stand model.

(d) Stratify the ANR area according to

- Existing LULC class
- Biomass growth potential
- Management (e.g., establishment year, treatment)

Delineate the boundary of each ANR stratum using a GPS coordinate, and present maps of the stratified project areas in the PD.

II.1.2.3 Step 2C – Define Land Transitions between LULC classes and Forest Strata

A land transition is a change from one LULC class or forest stratum into another LULC class or forest stratum. It is a process of change and evolution and not a condition or state. The main land transitions are deforestation, forest degradation, reforestation and regeneration. A list must be prepared of the transitions that are considered by the project proponents by analyzing a matrix combining all relevant LULC class and forest strata subject to deforestation, forest degradation, and regeneration and reforestation. Assisted reforestation is not allowed under this methodology. However, natural regeneration or reforestation through natural succession must be included as otherwise baseline GHG stocks will be underestimated. Note that assisted natural regeneration is allowed under this methodology.

Land that only temporarily transitions from forest to non-forest, and transitions back to forest after a short while is considered “temporarily unstocked forest” and may not be counted towards the total deforestation and reforestation rate. For every deforestation transition, select the maximal period that the “from” forest class can be out of forest cover and is temporarily unstocked. Use a default value of two years, unless project-specific conditions demand a different period.

Table 7. Example LULC and forest strata transition matrix showing all possible transitions.

To \ From		Forest stratum						Non-forest LULC class					
		EG1	EG2	EG3	MX1	MX2	MX3	DGL	GRL	CRL	STL	WTL	OTL
Forest stratum	EG1		DGE21					RFDE1	RFGE1	RFCE1			
	EG2	RGE12		DGE32									
	EG3		RGE23										
	MX1					DGM21		RFDM1	RFGM1	RFCM1			
	MX2				RGM12		DGM32						
	MX3					RGM23							
Non-Forest LULC class	DGL	DFE1D	DFE2D	DFE3D	DFM1D	DFM2D	DFM3D						
	GRL												
	CRL	DFE1C	DFE2C	DFE3C	DFM1C	DFM2C	DFM3C						
	STL	DFE1S	DFE2S	DFE3S	DFM1S	DFM2S	DFM3S						
	WTL												
	OTL												

EG1-EG3 = evergreen forest classes with increasing carbon density, MX1-MX3 = mixed/deciduous forest classes with increasing carbon density, PL1-PL2 = plantation forest classes with increasing carbon density, DGL = degraded land, GRL = grassland, CRL = cropland, STL = settlement, WTL = wetland, OTL = other land

II.1.2.4 Step 2D – Analyze Historical LULC Class and Forest Strata Transitions

This step produces: (1) a series of LULC class and forest strata maps of the reference region from the historical reference period, (2) a forest cover benchmark map, and (3) a table of historical deforestation and forest degradation rates. First, all images from the historical reference period must be classified according to the LULC class and forest strata definitions outlined above in section II.1.2.2. Existing classification or stratification maps can be used if the classes in these maps can be matched to these LULC class and forest strata definitions developed according to this methodology. The map for the start of the crediting period clearly indicates which areas are forested and which are not following the relevant forest definition. The time series of historical LULC and forest strata maps is then used to produce a table of historical deforestation, natural reforestation, forest degradation, and natural regeneration rates.

A number of sensors exist for LULC classification and forest stratification based on imagery from optical, RADAR, or LiDAR sensors, on airborne or satellite platforms. Since the most appropriate sensor is dependent on project-specific conditions and requirements, this methodology does not prescribe one specific sensor, but rather a set off main methodological steps. The analysis of land cover change shall be performed by processing and analyzing remote sensing data in three steps:

(1) Pre-processing of remote-sensing data

(2) Classification and stratification

(3) Accuracy assessment using ground-truth data.

II.1.2.4.1 Pre-processing

Pre-processing includes:

1. **Geometric corrections** to ensure that images in a time series overlay properly to each other and to other GIS maps used in the analysis (i.e. for post-classification stratification). The average location error between two images (RMSE) must be less than one pixel.
2. **Cloud and cloud shadow removal** using additional sources of data (e.g., radar, aerial photographs, field surveys). If clouds and cloud shadows cannot be removed, the following rules will be followed.
    a. Areas in the **reference region** covered by clouds or cloud shadows shall be masked out and excluded from the calculation of the deforestation rates. The maximally allowed cloud cover for use of any image is 20%.
    b. Areas covered with clouds and cloud shadows in the **project and leakage areas at the start of the crediting period** must be excluded from the calculations of GHG benefits until more information is available. It is essential to prove the forest cover status in the project and leakage areas at the start of the crediting period. If part of the project area is covered with clouds or cloud shadows and no other data can be found to demonstrate its LULC cover at the beginning of the crediting period, this area must be excluded from the calculation of GHG benefits until the status of the forest cover can be demonstrated using remote sensing data. Until then, no GHG benefits may be claimed from this area, and no NERs can be generated from this area.
    c. When clouds or cloud shadows are present in the **project and leakage areas after the project has started**, the calculation of the GHG benefits must be postponed until cloud-free remote sensing data is available in a subsequent monitoring period. These temporarily halted

NERs may be added to the NERs generated in the subsequent monitoring period.

3. **Reduction of haze**, as needed.
4. Apply **radiometric corrections** to ensure that identical objects have the same spectral response in multi-temporal datasets.

See Chapter 3 of the sourcebook on REDD (Brown et al., 2008) or consult experts and literature for further advice on pre-processing techniques. Duly record all pre-processing steps for later reporting.

II.1.2.4.2 LULC Classification and Forest Stratification

As specified before, a number of techniques exist for LULC classification and forest stratification based on imagery from optical, RADAR, or LiDAR sensors, on airborne or satellite platforms combined with ancillary spatial data such as roads and settlements, and data from field surveys. Such techniques include maximum likelihood, neural networks, and decision trees. Since the most appropriate technique is dependent on project-specific conditions and requirements, this methodology does not prescribe one specific technique. The selection of the relevant ancillary data is project-specific, and cannot be prescribed here. Relevant ancillary data may include:

- **Biophysical data** (e.g., climate or ecological zone, soil and vegetation type, elevation, rainfall, aspect, etc.). The IPCC 2006 Guidelines for National GHG Inventories provide default climate and soil classification schemes in Annex 3A.5 and advice on classifying LULC areas in section 3.3.2,
- **Disturbance indicators** (e.g., vicinity to roads or settlements; concession areas),
- **Age** (in case of plantations and secondary forests),
- **Land management** categories (e.g., protected forest, logging concession, indigenous reserve, etc.).

Duly report all interpretation and classification steps, sources of ancillary data, and techniques in the PD.

II.1.2.4.3 Map Accuracy Assessment Using Ground-Truthing Data

A measure of the accuracy of the LULC classification and forest stratification is required using independent field data, remote sensing data, and other ground-truthing data. An accuracy assessment must be done separately for LULC classification and forest stratification.

Table 8. Accuracy discounting factors for LULC classification

Accuracy attained	Discounting factor for emission reductions from avoided deforestation based on the accuracy of LULC classification $u_{classification}$	Discounting factor for emission reductions from avoided degradation based on the accuracy of forest stratification $u_{stratification}$
>95%	0.9	0.9
90-95%	0.8	0.8
85-90%	Project is not eligible	0.7
80-85%	Project is not eligible	0.6
<80 %	Project is not eligible	0 (exclude emission reductions from avoided forest degradation)

The accuracy of discerning broad LULC classification is used to discount credits from avoiding deforestation; the accuracy of discerning forest strata is used to discount credits from avoiding forest degradation. The discounting factors that must be used are presented in Table 8. Equation 1 explains how to apply the discounting factors for the calculation of NERs. Because the fine classification of forest land into different carbon density classes is more challenging than the broad classification into forest types or forest/non-forest land (Brown et al., 2008), different accuracy thresholds and discounting factors are imposed. A minimal accuracy of 90% is required for discerning forest from non-forest, and a minimal accuracy of 80% is required for discerning different forest biomass classes. The discounting factors are fixed until the next baseline update.

Step 1: Determine the accuracy of LULC classification. Because there is only one forest LULC class, classification does not distinguish among forest biomass density classes, which are all classified as “forest”. The accuracy is calculated based on a database of locations and their corresponding correct classification (as determined by ground-surveys or through visual interpretation of higher resolution data). Subsequently, a confusion matrix must be created to assess the accuracy. Report the overall accuracy, and the commission and omission errors (see Congalton, 1991 or Pontius, 2000 for an in-depth explanation). Use the smallest accuracy of all maps to calculate the discounting factor based on Table 8. If the accuracy of broad classification is smaller than 90%, the project is not eligible under this methodology.

Step 2: Determine the accuracy of forest stratification. The accuracy is calculated by comparing the actual carbon density of all field sampling plots, with the predicted carbon density class from the forest stratification map. Report the proportion of the points which are classified conservatively, i.e. the proportion of points that have an actual carbon density higher or equal than the predicted carbon density, and the commission and omission errors. Use the smallest accuracy of all maps to calculate the discounting factor based on Table 8. If the accuracy of broad classification is smaller than 80%, credits from avoided degradation must be excluded. However, in the latter case, credits from avoided deforestation may still be claimed subject to the accuracy requirements explained in step 1.

II.1.2.5 Step 2E – Summarize all Historical LULC Class and Forest Strata Transitions

For every pair of subsequent images in the historical reference period, calculate the area of each LULC class and forest strata transition category (Table 9). Note that for deforestation, lands should have been without forest cover for longer than the period defined as temporarily un-stocked.

It is necessary to summarize these data in a LULC Change Matrix (see Table 9 for an example). In addition, the PD must contain a table which contains the overall areas (ha) of deforestation, reforestation, forest degradation, and regeneration for each sub-period. These data will be used to project future land use change (section II.1.5.1).

Table 9. Example LULC and forest strata transition matrix from initial state (top row) to final state (left column).

	From	Forest strata								
To		EG1	EG2	EG3	MX1	MX2	MX3	PL1	PL2	...
Forest strata	EG1		50							
	EG2	10		20						
	EG3		20							
	MX1					30				
	MX2				5		20			
	MX3					8				
	PL1	10	5	5	25	30	25			
	PL2							10		
Non-forest LULC class	DGL	50	40	30	70	90	70			
	GRL									
	CRL	20	30	10	20	10	10			
	STL	5	5	7	4	8	4			
	...									

Values are in ha yr^{-1}. Empty cells indicate no or insignificant change.

Reporting Requirements, include in the PD sections 2.3 and 2.4

1. List of all spatial, remote sensing and field observation data sources with their characteristics as listed in Table 5.
2. Report on the stratification procedure
    a. Variables were used to stratify the area.
    b. Detailed map of the stratification.
    c. In case of a forest stratum on which ANR activities are planned, a description of all the site preparation activities planned.
    d. Detailed management plan of all the activities planned.
3. Description of each LULC class and forest stratum
    a. **Name** and code of the LULC class or forest stratum
    b. **Criteria and thresholds** used to distinguish the LULC class or forest stratum from other classes or strata (spectral and other stratification criteria) for the reference region including the areas on which ANR activities are proposed.
    c. **Seasonality of biomass and thresholds:** include information on seasonality (leaf-off period) for deciduous trees.
    d. **Management description.** List all relevant aspects for understanding carbon stock changes within each class such as rotation cycle duration or harvesting intensity.
4. Description of each land transition
    a. Rationale on which **transitions are included.** Summarize the included land transition categories in a land transition matrix (see Table 6).
    b. Rationale on the decision of the period of **temporarily un-stocked**, for every deforestation transition.
5. Remote sensing-based LULC classification
    a. Description of the **methodology** used for classification and stratification.
    b. **LULC class and forest stratum map** of each image in the historical reference period.
    c. **Confusion matrix** for every LULC class and forest stratum map, and values for the commission and omission errors.
    d. Tables containing the overall areas (ha) of deforestation, degradation, and regeneration for each sub-period.

II.1.3 Step 3 – Analyze the Agents and Drivers of Deforestation

An **agent** of deforestation is the social group, community, or company involved in deforestation or forest degradation. The **driver** of deforestation relates to the reason why they deforest or degrade the forest. Deforestation can be the result of a short-term process (e.g., forest clear-cutting) or a gradual progressive forest degradation. Therefore, agents/drivers of deforestation are often hard to distinguish from agents/drivers of forest degradation. As a consequence, the term deforestation agents/drivers is used for deforestation and degradation agents/drivers throughout this section. This methodology allows the generation NERs from reducing biomass loss due to different categories drivers of deforestation.

1. Fuel-wood collection or charcoal production
2. Human-induced forest fires
3. Conversion of forest land to crop-land or grazing land
4. Conversion of forest land to settlements
5. Illegal logging of timber for commercial on-sale
6. Logging of timber for local and domestic use

The PD must contain an analysis of the deforestation agents and drivers by performing the following four sub-steps (Angelsen and Kaimowitz, 1999; Chomitz et al., 2006).

1. Identification of **drivers** of deforestation and forest degradation
2. Assessing the relative importance of the drivers of deforestation and forest degradation
3. Identification of the **quantitative driving variables** related to the agents and drivers of deforestation and forest degradation

If this analysis reveals that deforestation agents and drivers are not similar in the reference region compared to the project area, the size and location of the reference region may have to be iteratively altered.

II.1.3.1 Step 3A – Identify Deforestation and Forest Degradation Drivers

For each of the six included categories of drivers covered by this methodology that are present in the reference region, the main agents must be identified. Agents of deforestation may include small-scale farmers, encroachers, hunters, ranchers, illegal loggers, or plantation companies. In some cases, one or more of the six general drivers need to be sub-divided into separate individual drivers depending on the different agents using the driver. For example, the general driver "human-induced forest fires" might be sub-divided into "forest fires induced by project participants to clear the land" and "forest fires induced by migratory hunters to concentrate forest game". The separation is necessary because leakage risks and mitigation potentials are significantly different between the two. A qualitative narrative on the broader underlying forces determining the agents' motivations for deforestation and forest degradation must be included. Where relevant to a driver, the following aspects must be considered in this narrative:

- Population pressure
- Poverty
- War and other types of conflicts and their effects
- Changes in policies related to subsidies, payments for environmental services, and credits
- Property and land tenure regime
- Market forces influencing land and commodity prices

II.1.3.2 Step 3B – Assess the Relative Importance of the Deforestation Drivers

The relative contribution of each of the deforestation drivers to the total historical deforestation and forest degradation is estimated in two steps: (1) estimating the absolute annual carbon loss per driver, and (2) estimate the relative contribution of each driver to the total carbon loss from deforestation and degradation.

Sub-Step 1: **Estimating the *absolute* annual carbon loss per driver** using the formulas in Table 10, which are based on GPG-LULUCF.

Table 10. Formulas to calculate the absolute annual carbon loss per deforestation or forest degradation driver category

Nr.	Driver category	Annual carbon loss
1	Fuel-wood collection or charcoal production	$$L_1 = FW_{baseline} \cdot D \cdot BEF_2 \cdot CF \quad (3)$$ (Equation 3.2.8 from GPG-LULUCF)
2	Human-induced forest wildfires	$$L_2 = \sum_{i=1}^{nrStrata} \Delta area_{baseline,fire}(i) \cdot E \cdot P \cdot C(i) \cdot CF \quad (4)$$ (Equation 3.2.9 from GPG-LULUCF)
3	Conversion of forest land to crop-land	$$L_3 = CF \cdot \sum_{i=1}^{nrStrata} \left(\Delta area_{baseline,cropland}(i) \cdot \left(C(i) - C(cropland)\right)\right) \quad (5)$$ (Equation 3.3.8 from GPG LULUCF)
4	Conversion of forest land to settlements	$$L_4 = CF \cdot \sum_{i=1}^{nrStrata} \left(\Delta area_{baseline,settlement}(i) \cdot \left(C(i) - C(settlement)\right)\right) \quad (6)$$ (Equation 3.3.8 from GPG LULUCF)
5	Illegal logging of timber for commercial on-sale	$$L_5 = IT_{baseline} \cdot D \cdot BEF_2 \cdot CF \quad (7)$$ (Equation 3.2.7 from GPG-LULUCF)
6	Logging of timber for local and domestic use	$$L_6 = DT_{baseline} \cdot D \cdot BEF_2 \cdot CF \quad (8)$$ (Equation 3.2.7 from GPG-LULUCF)

where:

L_i = Annual carbon loss associated with driver i. [Mg C yr^{-1}]

$FW_{baseline}$	=	Annual volume of fuelwood gathering in the baseline scenario, measured from (in order of preference) (1) participatory rural appraisals conducted by project proponents; (2) recent (<10 yr) peer-reviewed scientific literature in the reference region, or (3) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region. If emission reductions from avoided degradation were excluded due to insufficient accuracy and credits from introducing fuel-efficient woodstoves are included, $FW_{baseline}$ must be estimated based on participatory rural appraisals in which at least 100 households or 5% of the households in the project area, whichever is smallest, are sampled. [m^3 yr^{-1}]
D	=	Basic wood density, estimated using Table GPG-LULUCF 3A.1.9. [Mg DM m^{-3}]
BEF_2	=	Biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark), estimated using GPG-LULUCF Table 3A.1.10. [-]
CF	=	Carbon fraction of dry matter (default = 0.5). [Mg C (Mg DM)$^{-1}$]
$nrStrata$	=	Number of deforestation and forest degradation strata. [-]
$area_{baseline,fire}(i)$	=	Forest areas in the project area affected by disturbances from forest fires, measured from (in order of preference) (1) participatory rural appraisals conducted by project proponents; (2) recent (<10 yr) peer-reviewed scientific literature in the reference region, or (3) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region. [ha yr^{-1}]
E	=	Average combustion efficiency of the above-ground tree biomass (dimensionless). Use the following sources (in order of preference): (1) project-specific measurements, (2) regionally valid estimates, (3) estimates from Table 3.A.14 of IPCC GPG LULUCF, (4) if no appropriate combustion efficiency can be used, the IPCC default of 0.5. [-]
P	=	Average proportion of mass burnt from the above-ground tree biomass; estimate from GPG-LULUCF Table 3A.1.13 relative to C_{class1} . [-]
$C(i)$	=	Average total carbon stock density for forest stratum i. [MT C ha^{-1}]

$\Delta area_{baseline,cropland}(i)$	=	Forest area converted from forest stratum i to cropland at the beginning of the crediting period; measure from (in order of preference) (1) remote sensing analyses in the reference region, (2) participatory rural appraisals conducted by project proponents; (3) recent (<10 yr) peer-reviewed scientific literature in the reference region, or (4) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region. [ha yr^{-1}]
$C(i)$, $C(cropLand)$, and $C(settlement)$	=	Average total carbon stock density of forest stratum i, cropland, or settlement, respectively; measured using forest sampling plots. [Mg DM ha^{-1}]
$B_{cropland}$	=	Biomass stock density of cropland); measure using forest sampling plots. [Mg DM ha^{-1}]
$\Delta area_{baseline,settlement}(i)$	=	Average forest area converted from forest stratum i to settlement land; measure from (in order of preference) (1) remote sensing analyses in the reference region, (2) participatory rural appraisals conducted by project proponents; (3) recent (<10 yr) peer-reviewed scientific literature in the reference region, or (4) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region. [ha yr^{-1}]
$B_{settlement}$	=	Biomass stock density of cropland); measure using forest sampling plots. [Mg DM ha^{-1}]
$IT_{baseline}$	=	Annually extracted volume of illegally harvested timber, roundwood; measure from (in order of preference) (1) participatory rural appraisals conducted by project proponents; (2) recent (<10 yr) peer-reviewed scientific literature in the reference region, (3) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region, or (4) recent (<10 yr) non peer-reviewed reports by local organizations. [m^3 yr^{-1}]
$DT_{baseline}$	=	Annually extracted volume of timber for domestic and local use, roundwood; measure from (in order of preference) (1) participatory rural appraisals conducted by project proponents; (2) recent (<10 yr) peer-reviewed scientific literature in the reference region, (3) recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region, or (4) recent (<10 yr) non peer-reviewed reports by local organizations. [m^3 yr^{-1}]

Sub-Step 2: **Estimating the *relative* contribution of each driver** to the total carbon loss from degradation and deforestation. Carbon losses must be separated into deforestation and degradation. In case of conversion of forestland to cropland and settlements, all of the carbon loss is related to deforestation. However, drivers that have a more gradual carbon decrease (fuel-wood collection, wildfires, and logging) will first lead to forest degradation, and eventually deforestation when biomass density becomes smaller than the arbitrary threshold implied under the forest definition. For example, a loss of 25 Mg biomass per hectare on a well-stocked forest of 200 Mg biomass per hectare is defined as deforestation, while the same loss on a poorly-stocked forest of 50 Mg standing biomass per hectare may be forest degradation. The proportion of the carbon loss from fuel-wood collection, wildfires, and logging that leads to deforestation versus forest degradation is estimated depending on specific conditions outlined in Table 11.

Table 11. Proportion of carbon loss leading to deforestation vs. forest degradation for different drivers.

Driver		Condition	$proportion_{DF}(i)$	$proportion_{DG}(i)$
1	Fuel-wood collection or charcoal production	More than 50% of all fuel-wood is collected from dead-wood	75%	25%
		More than 50% of all fuel-wood is collected from green wood	25%	75%
2	Human-induced forest wildfires	No evidence of crown fires in the last 10 years.	25%	75%
		Some large crown fires occurred in the last ten years, but on less than 1% of the forest area.	50%	50%
		Large crown fires occurred in the last ten years, but on more than 1% of the forest area.	75%	25%
3	Conversion of forest land to crop-land		100%	0%
4	Conversion of forest land to settlements		100%	0%
5	Illegal logging of timber for commercial on-sale	More than 50% of the illegal timber logging occurs as clear cutting[1].	75%	25%
		25-50% of the illegal timber logging occurs as clear cutting.	50%	50%
		Less than 25% of illegal logging occurs as clear-cutting	25%	75%
6	Logging of timber for local and domestic use	More than 50% of the timber logging for domestic use occurs as clear cutting.	75%	25%
		25-50% of the illegal timber logging for domestic use occurs as clear cutting.	50%	50%
		Less than 25% of illegal logging for domestic use occurs as clear-cutting	25%	75%

The total carbon loss due to deforestation versus forest degradation can be calculated as following:

[1] Clear-cutting is defined as removing more than 75% of the trees on an area that is at least the minimal required area of forest implied in the forest definition used.

$$\Delta C_{DF} = \sum_{i=1}^{nrDrivers} proportion_{DF}(i) \cdot L(i) \tag{9}$$

$$\Delta C_{DG} = \sum_{d=1}^{nrDrivers} proportion_{DG}(d) \cdot L(i) \tag{10}$$

where:

ΔC_{DF}	=	Total carbon loss due to deforestation. [Mg C yr^{-1}]
ΔC_{DF}	=	Total carbon loss due to degradation. [Mg C yr^{-1}]
$nrDrivers$	=	Number of drivers of deforestation or forest degradation. [-]
$proportion_{DF}(d)$ and $proportion_{DG}(d)$	=	Proportion of the gradual carbon loss that leads to deforestation or forest degradation, respectively, due to driver d. Estimate using the procedure detailed in Table 11.
$L(i)$	=	Annual carbon loss associated with driver i. [Mg C yr^{-1}]

The relative importance of the deforestation and forest degradation drivers can be calculated by combining the absolute carbon losses from Table 10 with the contributions from Table 11 using the formulas in Table 12.

Table 12. Formulas to calculate the relative importance of per deforestation and forest degradation driver to the total deforestation (DF) and forest degradation (DG)

Nr.	Driver Category	contribution to DF		contribution to DG	
1	Fuel-wood collection or charcoal production	$contribution_{DF}(1) = \frac{proportion_{DF}(1) \cdot L(1)}{\Delta C_{DF}}$	(11)	$contribution_{DG}(1) = \frac{proportion_{DG}(1) \cdot L(1)}{\Delta C_{DG}}$	(12)
2	Human-induced forest wildfires	$contribution_{DF}(2) = \frac{proportion_{DF}(2) \cdot L(2)}{\Delta C_{DF}}$	(13)	$contribution_{DG}(2) = \frac{proportion_{DG}(2) \cdot L(2)}{\Delta C_{DG}}$	(14)
3	Conversion of forest land to crop-land	$contribution_{DF}(3) = \frac{proportion_{DF}(3) \cdot L(3)}{\Delta C_{DF}}$	(15)	0	
4	Conversion of forest land to settlements	$contribution_{DF}(4) = \frac{proportion_{DF}(4) \cdot L(4)}{\Delta C_{DF}}$	(16)	0	
5	Illegal logging of timber for commercial on-sale	$contribution_{DF}(5) = \frac{proportion_{DF}(5) \cdot L(5)}{\Delta C_{DF}}$	(17)	$contribution_{DG}(5) = \frac{proportion_{DG}(5) \cdot L(5)}{\Delta C_{DG}}$	(18)
6	Logging of timber for local and domestic use	$contribution_{DF}(6) = \frac{proportion_{DF}(6) \cdot L(6)}{\Delta C_{DF}}$	(19)	$contribution_{DG}(6) = \frac{proportion_{DG}(6) \cdot L(6)}{\Delta C_{DG}}$	(20)

where:

$contribution_{DF}(i)$	=	Relative contribution of driver i to the total deforestation. [-]
$contribution_{DG}(i)$	=	Relative contribution of driver i to the total forest degradation. [-]
$proportion_{DF}(i)$	=	Proportion of the gradual carbon loss that leads to deforestation. [-]
$proportion_{DG}(i)$		Proportion of the gradual carbon loss that leads to degradation. [-]
ΔC_{DF}	=	Total carbon loss due to deforestation. [Mg C yr^{-1}]
ΔC_{DF}	=	Total carbon loss due to degradation. [Mg C yr^{-1}]
$L(i)$	=	Annual carbon loss associated with driver i. [Mg C yr^{-1}]

II.1.3.3 Step 3C – Analyze of the Mobility of Each Deforestation and Forest Degradation Driver

The geographical extent of leakage is, in part, dependent on the mobility of each deforestation agent. It must be determined how far each deforestation agent is willing to go to acquire the forest resource or clear the land for cropland, grassland or settlement. In other words, how far are people expected to walk, bike or drive for collecting fuel-wood, illegal logging, or charcoal production?

- For every driver of deforestation, report the main mode of transportation used by the main agent of deforestation of that driver: on foot, bike, scooter, motorcycle, car, or truck. Substantiate the choice with data from (in order of preference) (1) social appraisals conduction by project proponents, (2) recent (< 10 yr) peer-reviewed scientific literature conducted among groups similar to the deforestation agents of the project, (3) communications by local socio-cultural and anthropological experts.

- Present a table of the average speed by which each identified mode of transportation can cross each of the LULC classes and road categories, such as tracks, seasonally accessible small roads, and year-round accessible two-lane roads. Note the average speed on land with restricted access, such as national parks, as 0. Substantiate the choice with data from (in order of preference) (1) social appraisals conducted by project proponents, (2) recent (< 10 yr) peer-reviewed scientific literature conducted among groups similar to the deforestation agents of the project, (3) communications by local socio-cultural and anthropological experts.
- Drivers that are less geographically constrained will still be confined to a "sphere of influence". For example, timber concessions might be granted by provincial officials. In this case, leakage will most likely not extend beyond the boundaries of the province, and the sphere of influence of the driver is provincial. However, if the granting of large economic land concessions occurs at a national level, the prevention of project areas being converted into economic land concessions may lead to an increase in economic land concessions elsewhere in the country. In this case, the sphere of influence of the driver is national.

II.1.3.4 Step 3D – Identify the Quantitative Driving Variables of Deforestation and Forest Degradation

For each identified driver, provide:

1. Non-spatial driving variables that explain the **quantity** of land cover change (to be used in section II.1.5.1). Project proponents must present the following variables in the PD:
    - Rural wages,
    - Prices and demand of agricultural products,
    - Costs of agricultural inputs,
    - Population density.
2. Spatial driving variables that explain the **location** of land cover change are also called "predisposing factors" (De Jong, 2007) (to be used in section II.1.5.2). Project proponents must select one or more of the following variables that potentially explain the location of deforestation and forest degradation
    - Access to forests (such as vicinity to existing roads, railroads, navigable rivers and coastal lines),
    - Slope,
    - Aspect,
    - Proximity to markets,
    - Proximity to industrial facilities (e.g., sawmills, agricultural products processing facilities, etc.),
    - Proximity to forest edges,
    - Proximity to settlements,

- o Soil fertility and rainfall,
- o Management category of the land (e.g., national park, logging concession, indigenous reserve, etc.).

Reporting Requirements, include in PD section 1.7
For each deforestation driver, provide the following information: 1. **Name** of the agent or agent group (there may be multiple agents) causing the deforestation. 2. Brief description of the **main social, economic, cultural and other relevant features** of each agent, including the broader underlying motivation for deforestation and forest degradation. 3. Brief assessment of the most likely **development of the population size** of the identified agents in the reference region and project area. 4. Estimate of the **relative contribution** of this driver to the overall deforestation quantity, using the procedures outlined in this section. 5. **Mobility** of the agents: analysis of transportation mode, analysis of the relative time needed to reach the project area, sphere of influence. 6. For every deforestation driver, list the non-spatial and spatial **quantitative driving variables** for each deforestation driver. Demonstrate that the identified variables are in fact explaining deforestation.

Once the agents and drivers of deforestation have been identified, project proponents must re-assess the similarity between the project area and the reference region, according to the procedure in section II.1.1.2. If necessary, adjust the area and location of the reference region to ensure that the same drivers of deforestation are acting in both the reference region and the project area.

II.1.4 Step 4 – Determine Emission Factors for All Included Transitions

For each LULC class or forest stratum that could be subject to a transition as identified in section II.1.2.3, it is necessary to determine the average carbon stock density, based on **permanent sampling plots on forest LULC classes** and **non-permanent sampling plots on non-forest LULC classes**. The number of plots and their location must be determined in a stratified sampling design. The following steps are to be followed:

1. Identify the LULC classes and forest strata for which carbon stocks are to be quantified.
2. Review existing biomass and biomass increment data for comparison with field measurements.
3. Determine the sample size per LULC class or forest stratum.
4. Measure carbon density stocks of each LULC class or forest stratum.
5. Calculate emission factors for each land transition category.

II.1.4.1 Step 4A – Identify the LULC Classes and Forest Strata for which Carbon Stocks are to be Quantified.

Present a table of the LULC classes and forest strata that are likely to be subject to transitions within the project area or anticipated leakage area based on the land transition matrix.

II.1.4.2 Step 4B – Review Existing Data of Biomass Stock Densities and Biomass Net Annual Increments

For the purpose of sampling design and quality assurance of the measured values, all existing data on biomass stock densities must be reviewed. Sources that must be consulted include (in order of preference): (1) peer-reviewed scientific literature conducted within the reference region, (2) peer-reviewed scientific literature from an area similar to the reference region, (3) non peer-reviewed reports or studies from the reference region or similar areas. Sources that contain a measure of the variation of the values (range, standard deviations, standard errors, or coefficients of variation) are specifically useful, since these can be used for preliminary determination of the number of sampling plots required during field sampling. For every data source used, note the following items (Brown et al., 2008):

- Methodology (field inventory, extrapolation from satellite imagery, ecosystem model, or GIS analysis).
- Number of measurement plots used.
- Whether all species are included in the sampling.
- The minimum DBH of measured trees in the biomass inventory.
- Region in which the samples were taken.

Whereas the GHG benefits from avoided deforestation and avoided forest degradation are based on observed transitions between LULC classes and forest strata, the GHG benefits from ANR activities are based directly on the empirically observed increases in biomass stock densities. Therefore, a correct accounting of the GHG benefits from ANR activities requires a sound baseline natural regeneration rate. Therefore, all existing data on net annual increments of biomass carbon stocks must be reviewed. Sources that must be consulted include (in order of preference): (1) values measured by the project proponents in the project area using the methods used for forest inventories discussed in this methodology, (2) national or local growth curves and tables that are usually used in national or local forest inventories, (3) values from peer-reviewed literature, report the items above, (4) values from GPG-LULUCF Table 3A.1.5. These values are representative for regeneration in well-managed forests, and will therefore be conservative.

These values must be reported as $NAI(i)$ for every stratum i on which ANR activities are planned.

II.1.4.3 Step 4C – Determine the Sample Size per LULC Class or Forest Stratum

The determination of the sample size (number of sampling plots) required per LULC class and forest strata that are identified in II.1.4.1 is dependent on (1) the required precision at a given confidence level and (2) the anticipated variance in the specific LULC class and forest strata. Extra measurement plots must be installed within the ANR areas to reliably estimate the increase in carbon density. The following steps are followed to determine a sampling design, which follow method I (sampling with replacement) of the CDM methodological tool "Calculation of the number of sample plots for measurements within A/R CDM project activities"[2].

Sub-Step 1: Select a preliminary sample plot size (AP), desired level of precision p (must be less than 10%), and confidence level (must be at least 95%).

Sub-Step 2: Calculate the areas of each LULC class or forest stratum in the project area based on the stratification in section II.1.2 (A_i).

Sub-Step 3: Calculate the maximum possible number of sample plots in the project area and the maximum possible number of sample plots in stratum i.

$$N = \frac{size_{projectArea}}{AP}; N_i = \frac{area(i,0)}{AP} \quad (21)$$

where:

N	=	Maximum possible number of sample plots in the project area. [-]
$size_{projectAre}$	=	Total size of all strata, e.g. the total project area. [ha]
AP	=	Sample plot size (constant for all strata). [ha]
i	=	Index for stratum. [-]
N_i	=	Maximum possible number of sample plots in stratum i. [-]
$area(i,0)$	=	Total size of stratum i at the beginning of the crediting period. [ha]

Sub-Step 4: Estimate the approximate average value of the aboveground tree biomass stock Q_i, and the associated standard deviation st_i for each LULC classes and forest stratum i, based on (in order of preference): (1) preliminary sampling by project proponents in approximately 5 plots per LULC class or forest stratum, (2) peer-reviewed scientific literature from identical forest systems as the ones in the reference region. Estimate the allowable error E_i based on the desired level of precision (at most 10%).

$$E_i = Q_i \cdot p \quad (22)$$

where:

E_i	=	Allowable error of the aboveground tree biomass. [Mg DM ha^{-1}]
Q_i	=	Approximate average value of the aboveground tree biomass of class or stratum i. [Mg DM ha^{-1}]
p	=	Desired level of precision (must be < 10%). [-]

Determine the total required number of sampling plots.

[2] http://cdm.unfccc.int/EB/031/eb31_repan15.pdf

$$\begin{cases} n = \dfrac{\left(\sum_{i=1}^{nrStrata} N_i \cdot st_i \cdot \sqrt{cost_i}\right) \cdot \left(\sum_{i=1}^{nrStrata} N_i \cdot st_i / \sqrt{cost_i}\right)}{\left(N \dfrac{E_1}{z_{\alpha/2}}\right)^2 + \sum_{i=1}^{nrStrata} N_i \cdot st_i^2} \\ n_i = n \cdot \dfrac{N_i \cdot st_i / \sqrt{cost_i}}{\sum_{i=1}^{nrStrata} N_i \cdot st_i / \sqrt{cost_i}} \end{cases} \quad (23)$$

where:

n	=	Sample size (total number of sample plots required) in the project area. [-]
n_i	=	Sample size for stratum i. [-]
$z_{\alpha/2}$	=	Value of the z-statistic; α must be smaller than 0.05 (implying a minimal confidence level of 95%); $z_{0.05/2}$=1.9599.
st_i	=	Expected of the standard deviation of the aboveground biomass of class or stratum i. [Mg DM ha^{-1}]
$cost_i$	=	Cost to sample stratum i. Set to 1 if costs are identical for all strata.

- **Sub-Step 5**: If the number of samples produced is impractical to collect, then increase the area of the sampling plots.

II.1.4.4 Step 4D – Select Sampling Plot Layout and Location

Further explanation on how to select the **layout of sampling plots** (form, nesting, etc.) can be found in Pearson et al. (2005).

For measuring and monitoring carbon density in the forest strata, a network of permanent forest sampling plots must be established. Due to the significant anthropogenic influence on non-forest land, it is not deemed feasible to install permanent sampling plots. Therefore, the average carbon stock density on non-forest LULC classes shall be assessed using non-permanent sampling plots.

Within a LULC class or forest stratum, the **location of sample plots** must be selected either systematically with a random start (see 2003 IPCC GPG-LULUCF) or randomly within a cell of a systematic grid (see Thompson, 2002). The randomization must be done *ex-ante* by a computer program. This is required to avoid subjective choice of plot locations. For each sample plot, record the observed LULC class, forest type, and estimated forest canopy closure.

Summarize the sampling framework following the guidance of section 4.3.3.4 of GPG LULUCF and the Sourcebook for LULUCF (Pearson et al., 2006) in the PD and provide a map and the coordinates of all sampling locations.

II.1.4.5 Step 4E – Measure Carbon Density Stocks

The total biomass stock density from a sampling plot is calculated by summing the aboveground, belowground, and dead-wood components of this plot:

$$B_{plot\text{-}wise}(i,p) = B_{AG,plot\text{-}wise}(i,p) + B_{BG,plot\text{-}wise}(i,p) + B_{LDW,plot\text{-}wise}(i,p) + B_{SDW,plot\text{-}wise}(i,p) \quad (24)$$

where:

$\boldsymbol{B_{plot\text{-}wise}(i,p)}$	=	Total biomass stock density of plot p within LULC class or forest stratum i. [Mg DM ha^{-1}]
$\boldsymbol{B_{AG,plot\text{-}wise}(i,p)}$	=	Aboveground tree biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{B_{BG,plot\text{-}wise}(i,p)}$	=	Belowground tree biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{B_{LDW,plot\text{-}wise}(i,p)}$	=	Lying dead-wood biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{B_{SDW,plot\text{-}wise}(i,p)}$	=	Standing dead-wood biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]

The biomass stock density of stratum $\boldsymbol{i}$ and associated statistics are calculated on the plots $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$.

$$B(i) = average\left(B_{plot\text{-}wise}(i,p)\right) \tag{25}$$

$$stdev\big(B(i)\big) = stdev\left(B_{plot\text{-}wise}(i,p)\right) \tag{26}$$

$$stderr\big(B(i)\big) = \frac{stdev\big(B(i)\big)}{\sqrt{n_i}} \tag{27}$$

$$HCWI\big(B(i)\big) = t_{0.95,n-1} \cdot stderr\big(B(i)\big) \tag{28}$$

$\boldsymbol{B(i)}$	=	Average total biomass stock density of LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{B_{plot\text{-}wise}(i,p)}$	=	Total biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{stdev\big(B(i)\big)}$	=	Standard deviation of the total biomass stock density of LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{stderr\big(B(i)\big)}$	=	Standard error of the average of the total biomass stock density of LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{n_i}$	=	Number of sampling plots of LULC class or forest stratum $\boldsymbol{i}$. [-]
$\boldsymbol{HWCI\big(B(i)\big)}$	=	Half-width of the confidence interval around the average of the total biomass stock density of LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]

The average total carbon stock is calculated by multiplication with the carbon fraction:

$$C(i) = CF \cdot B(i) \tag{29}$$

where:

$\boldsymbol{C(i)}$	=	Average total carbon stock density of LULC class or forest stratum $\boldsymbol{i}$. [MT C ha^{-1}]
$\boldsymbol{CF}$	=	Carbon fraction of dry matter in wood (default = 0.5). [Mg C (Mg DM)$^{-1}$]
$\boldsymbol{B(i)}$	=	Total biomass stock of LULC class or forest stratum $\boldsymbol{i}$. [MT C ha-1]

The exact measurement of above-ground and below-ground tree carbon must follow international standards (IPCC GPG LULUCF 2003). These measurements are explained in detail in Pearson et al. (2006) and CDM approved methodology AR-AM0002 "Restoration of degraded lands through afforestation/reforestation". A step-by-step Standard Operations Procedure for field measurements should be prepared and contain a detailed, step-by-step explanation of all of the required field-work. This document will ensure consistency during the crediting period by standardizing sampling procedures from year to year.

- **Aboveground biomass**, $\boldsymbol{B_{AG}(i,p)}$. Measure the DBH of all trees with a DBH > 5 cm within the sampling plot. Record the species. In permanent sampling plots, all trees must be tagged. The per tree above-ground carbon stocks are estimated by relating the biomass to DBH using allometric equations applied to the tree and multiplying the carbon fraction of tree biomass. Sometimes the allometric equation will not provide above-ground biomass, but rather commercial/merchantable timber volume. This can be calculated into above-ground biomass by multiplying with a density of the wood, and a biomass expansion factor (BEF). Values of wood density can be found in Table 3A.1.9 of the GPG LULUCF or Reyes et al. (1992). BEF values can be found in Table 3A.1.10 of IPCC GPG-LULUCF 2003.

$$B_{AG,plot\text{-}wise}(i,p) = \frac{\sum_{t=1}^{nrTrees(i,p)} f_{allometric}\big(DBH(t,i,p)\big)}{AP \cdot \cos\big(\theta(i,p)\big)} \tag{30}$$

where:

$\boldsymbol{B_{AG,plot\text{-}wise}(i,p)}$	=	Aboveground biomass in plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. [Mg DM ha^{-1}]
$\boldsymbol{nrTrees(i,p)}$	=	Number of trees in sample plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. [-]
$\boldsymbol{f_{allometric}(y)}$	=	Allometric relationship to convert DBH into biomass.

Use the following hierarchy to select the most appropriate allometric equation.

1. Allometric equations developed by project proponents
2. Allometric equations developed locally by groups other than project proponents
3. Allometric equations developed for forest types that are similar to the ones in the project as found in found in Appendix C of Pearson et al. (2005), or Tables 4.A.1. and 4.A.2. of the GPG LULUCF

$DBH(t,i,p)$	=	DBH of tree t within plot p of LULC class or forest stratum i. [cm]
AP	=	Size of a sampling plot. [ha]
$\theta(i,p)$	=	Slope of the land of plot p of LULC class or forest stratum i. See section 8 in Pearson et al. (2005). [m m^{-1}]

- **Belowground biomass**, $B_{BG}(i,p)$. The below-ground biomass pool is estimated from the above-ground biomass using a relationship between aboveground and belowground biomass, such as a root-to-shoot ratio.

$$B_{BG,plot\text{-}wise}(i,p) = f_{belowground}\left(B_{AG,plot\text{-}wise}(i,p)\right) \quad (31)$$

where:

$B_{BG,plot\text{-}wise}(i,p)$	=	Belowground biomass in plot p of LULC class or forest stratum i. [Mg DM ha^{-1}]
$f_{belowground}(y)$	=	Relationship between aboveground and belowground biomass, such as a root-to-shoot ratio. Use (in order of preference) 1. A relationship calculated from destructive sampling data obtained within the project area. 2. A relationship obtained from the local/national studies that closely reflect the conditions of the project activity. 3. Equations under section 8.2 of Pearson et al., 2005, or standard root-to-shoot ratios as found in Table 4.4 of the IPCC GPG-LULUCF 2003, and adapted by Brown et al., 2007.
$B_{AG,plot\text{-}wise}(i,p)$	=	Belowground biomass in plot p of LULC class or forest stratum i. [Mg DM ha^{-1}]

- **Lying dead-wood**, $B_{LDW}(i,p)$. Lying deadwood should be sampled using the line intersect method (Harmon and Sexton, 1996[3]). Two 50-meter lines are established bisecting each plot and the diameters of the lying dead wood (≥ 5 cm diameter) intersecting the lines are measured. The dead wood is then assigned to one of the three density states (sound, intermediate, and rotten). Volume of lying deadwood per unit area is calculated using the equation (Warren and Olsen, 1964[4]):

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[3] Harmon, M. E. and J. Sexton. (1996) Guidelines for Measurements of Woody Detritus in Forest Ecosystems. US LTER Publication No. 20. US LTER Network Office, University of Washington,, Seattle, WA, USA

[4] Warren, W.G. and Olsen, P.F. (1964) A line transect technique for assessing logging waste, *Forest Science* 10: 267-276.

$$B_{LDW,plot\text{-}wise}(i,p) = \frac{\sum_{d=1}^{nrDecompClasses} \pi \cdot D(d,i,p)^2 \cdot L \cdot \rho_{DW}(d) \cdot 10}{8 \cdot AP \cdot \cos(\theta(i,p))} \quad (32)$$

where:

$\boldsymbol{B_{LDW,plot\text{-}wise}(i,p)}$	=	Biomass of lying dead wood in sampling plot p of LULC class or forest stratum i. [MT C ha^{-1}]
$\boldsymbol{nrDecompClasses}$	=	Number of decomposition classes, default = 3 (1=sound, 2=intermediate, 3=rotten). [-]
$\boldsymbol{D(d,i,p)}$	=	Sum of diameters in decomposition class $\boldsymbol{d}$ (1=sound, 2=intermediate, 3=rotten) of sampling plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. [m]
$\boldsymbol{L}$	=	Length of the transect. [m]
$\boldsymbol{\rho_{DW}(d)}$	=	Basic density of dead wood in the density class d. [kg DM m^{-3}]
$\boldsymbol{AP}$	=	Size of a sampling plot, if necessary corrected for slope. [ha]
$\boldsymbol{\theta(i,p)}$	=	Slope of the land of plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$ (see section 8 in Pearson et al., 2005). [m m^{-1}]

- **Standing dead-wood**, $\boldsymbol{B_{SDW}(i,p)}$. Standing dead trees shall be measured using the same procedures used for measuring live trees with the addition of a decomposition class. The decomposition class of the dead tree and the diameter at breast height shall be recorded and the standing dead wood is categorized under the following four decomposition classes:

  1. Tree with branches and twigs that resembles a live tree (except for leaves)
  2. Tree with no twigs but with persistent small and large branches
  3. Tree with large branches only
  4. Bole only, no branches

  Biomass for dead trees in decomposition class 1 is estimated using the allometric equation for live trees. Biomass for dead trees in decomposition class 2-4 is estimated using Equation (32).

Within the PD, report the average $B(i)$, standard deviation $stdev(B(i))$, number of observations n_i, standard error around the mean $stderr(B(i))$, and half-width of the 95%-confidence interval around the mean $HCWI(B(i))$ for every LULC class or forest stratum i.

II.1.4.6 Step 4F – Calculate Emission Factors

The total emission factor is the sum of the carbon pool-related sources due to (1) changes in biomass between the LULC classes and forest strata and (2) any fire-related N_2O and CH_4 emissions from land class change.

II.1.4.6.1 Calculate Emission Factors Due to Changes in Carbon Stock Density Between LULC Classes and Forest Strata

Once the carbon stock densities are calculated, biomass carbon emission factors and their uncertainties for each LULC class or forest stratum transition are calculated as:

$$EF_{bio}(classStratum1 \rightarrow classStratum2) = \frac{44}{12} \cdot \big(C(classStratum2) - C(classStratum1)\big) \quad (33)$$

$EF_{bio}(classStratum1 \rightarrow classStratum2)$	=	Emission factor for change from LULC class or forest stratum 1 to 2. [MTCO2e ha^{-1}],
$classStratum1 \rightarrow classStratum2$	=	Land transition from LULC class or forest stratum 1 to 2.
$C(i)$	=	Carbon density of classes or forest stratum i. [MT C ha^{-1}]

The discounting factor for uncertainty around biomass stock densities measured with sampling plots can then be calculated as:

$$u_{inventory}(classStratum1 \rightarrow classStratum2) = \frac{44}{12} \cdot CF \cdot \frac{\sqrt{HWCI\big(B(classStratum1)\big)^2 + HWCI\big(B(classStratum2)\big)^2}}{EF_{bio}(classStratum1 \rightarrow classStratum2)} \quad (34)$$

where:

$u_{inventory}(classStratum1 \rightarrow classStratum2)$	=	Discounting factor for the emission factor for the transition from LULC class or forest stratum 1 to class 2 according to the uncertainty of the biomass inventory. [-]
$HWCI\big(B(classStratum1)\big)$ and $HWCI\big(B(classStratum2)\big)$	=	Half-width of the 95% confidence interval around the mean carbon stock density of LULC classes or forest strata 1 and 2. [MTCO2e ha^{-1}]

Note that a positive sign of EF_{bio} indicates a net sequestration of carbon, or an increase in the carbon stock, and a negative sign indications emission. List the estimated emission factors, the associated uncertainties, and the lower confidence limit per LULC class and forest strata category in a table in the PD (see Table 13 for an example). If for any transition, $u_{inventory}(classStratum1 \rightarrow classStratum2)$ is smaller than 0.75, the project is not eligible.

II.1.4.6.2 Calculate Emission Factors due to N_2O and CH_4 Emissions From Fire

Deforestation often is caused by fire. Therefore, next to the loss of the carbon from the tree biomass, $EF_{bio}(classStratum1 \rightarrow classStratum2)$, some transitions also releases N_2O and CH_4, $EF_{fire}(classStratum1 \rightarrow classStratum2)$, which are allowed to be accounted for in this methodology if sufficient data is available. If insufficient data on fire occurrence is available, emissions from fire may be conservatively omitted.

A calculation of the fire-related CH_4 and N_2O emissions requires estimating the importance of fire to the total amount of deforestation (factor F in the equation below), then quantifying this factor using data on forest fires during the historical reference period. A conservative approach (with smaller F values) is required if the quality of the data is poor. A rationale of choosing F must be included in the PD. The approach outlined in IPCC GPG-LULUCF 2003, Equation 3.2.19 is used here to calculate GHG emissions from biomass burning. These can be estimated as

$$EF_{fire}(classStratum1 \rightarrow classStratum2) = C_{min} \cdot E \cdot F \cdot P \cdot \left(\frac{44}{28} \cdot \frac{GWP_{N2O} \cdot ER_{N2O}}{r} + \frac{16}{12} \cdot GWP_{CH4} \cdot ER_{CH4}\right) \quad (35)$$

where:

$EF_{fire}(classStratum1 \rightarrow classStratum2)$	=	Total GHG emission from biomass burning. [MTCO2e ha^{-1}]
C_{min}	=	Minimal carbon stock density of all forest strata. [MT C ha^{-1}]
E	=	Average combustion efficiency of the above-ground tree biomass (dimensionless). Use the following sources (in order of preference): (1) project-specific measurements, (2) regionally valid estimates, (3) estimates from Table 3.A.14 of IPCC GPG LULUCF, (4) if no appropriate combustion efficiency can be used, the IPCC default of 0.5. [-]
F	=	Relative importance of fire in the total deforestation during the historical reference period, use $\frac{L_2}{\Delta C_{DF}+\Delta C_{DG}}$ from section II.1.3.2. [-]
P	=	Average proportion of mass burnt from the above-ground tree biomass; estimate from GPG-LULUCF Table 3A.1.13 relative to C_{class1}. [-]
GWP_{N2O} and GWP_{CH4}	=	Global Warming Potentials for N_2O and CH_4 (IPCC default values = 310 and 21 respectively, for the first commitment period). [-]
ER_{N2O} and ER_{CH4}	=	Emission ratios for N_2O (IPCC default values = 0.007 and 0.012 respectively). See Table 3A.1.15 in IPCC GPG-LULUCF 2003. [-]

r	=	Carbon-to-Nitrogen ratio of the wood. If no (lower) values are available, this can be conservatively approximated as 100, based on leaf litter analyses. [-]

Table 13. Example look-up table for emission factors (all values in MTCO2e ha^{-1})

Transition			Carbon pool-related emission factor (EF_{bio})		Fire-related emission factor (EF_{fire})	Total Emission Factor	
From	To	Code	average	HWCI	average	average	$uncertainty_{inventory}$
EG1	EG2	RGE12	75	15	5		
EG1	DGL	DFE1D					
EG1	CRL	DFE1C					
EG1	STL	DFE1S					
EG2	EG1	DGE21					
EG2	EG3	RGE23					
…	…	…					

HWCI = half-width of the 95% confidence interval,

PD Reporting requirements	PD section
1. Rationale on which LULC classes and forest strata are selected for quantification.	2.3
2. Table with existing data in carbon stock density measurements in the literature, including the methodology, number of sampling plots, whether all species were included, minimum DBH used, and region in which the samples were taken.	2.3
3. Table with baseline net annual increments due to natural regeneration rates. Report the same information on the data sources as for the previous PD requirement	2.3
4. Sample framework for collecting field data, including size, layout, and location.	2.3
5. Spreadsheet containing the calculations of carbon stock densities.	Supply Electronically
6. Statistical distributions (histograms) of all carbon stock measurements per LULC class and forest type.	2.3
7. Table with descriptive statistics on carbon stock densities per predicted LULC class or forest stratum i, including: • Average, $B(i)$ • Standard deviation, $stdev(B(i))$ • Number of observations, n_i • Standard error around the mean, $stderr(B(i))$ • Half-width of the 95%-confidence interval around the mean, $HCWI(B(i))$.	2.3
8. Look-up table with emission factors per LULC class and forest type, similar to Table 13.	2.4

II.1.5 Step 5 – Estimate *Ex-ante* Land Transition Rates under the Baseline Scenario

The goal of this step is to calculate all land transitions, including deforestation and reforestation, and forest degradation and regeneration under the baseline scenario. The procedure below calculates first the total deforestation and forest degradation rates, and also the relative regeneration and reforestation rates per forest stratum and LULC class. Subsequently, the total rates of deforestation and forest degradation are split into LULC class and forest stratum specific rates using a GEOMOD-type approach.

II.1.5.1 Step 5A – Calculate Total Rates of Deforestation and Forest Degradation in the Project Area

The total future deforestation and degradation rates are linearly interpolated from past trends. However, land scarcity of land may decrease rates to values below the maximal rates linearly interpolated on past trends. This is accounted for in sub-step 5D below.

Create a graph of the historical deforestation rates in the reference region (hectares per year) versus time (years) for each consecutive pair of images in the historical reference period. Create a similar graph of the historical degradation rates versus time. From these graphs, calculate the future deforestation and degradation rates using linear regression:

$$D_{referenceRegion,baselineScenario,DF}(t) = a_{DF} + b_{DF} \cdot t \quad (36)$$

$$D_{referenceRegion,baselineScenario,DG}(t) = a_{DG} + b_{DG} \cdot t \quad (37)$$

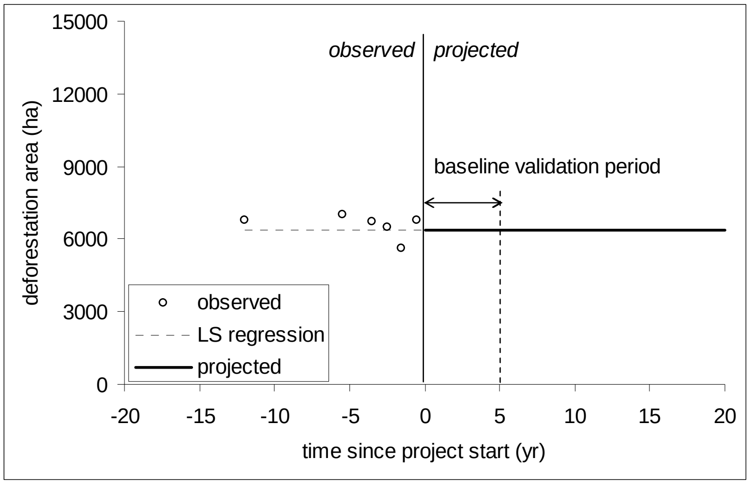
where:

$D_{baselineScenario,DF,referenceRegion}(t)$, $D_{baselineScenario,DG,referenceRegion}(t)$	=	Rate of deforestation/degradation within the reference region for year t. [ha yr^{-1}]
a_{DF} and a_{DG}	=	Intercept of the linear relationship between time and deforestation/degradation rate in the reference region during the historical reference period. [ha yr^{-1}]
b_{DF} and b_{DG}	=	Slope of the linear relationship between time and deforestation/degradation rate in the reference region during the historical reference period. [ha yr^{-2}]
t	=	Time since project start (negative before project start). [yr]

The coefficients a_{DF}, b_{DF}, a_{DG}, and b_{DG} can be calculated as follows:

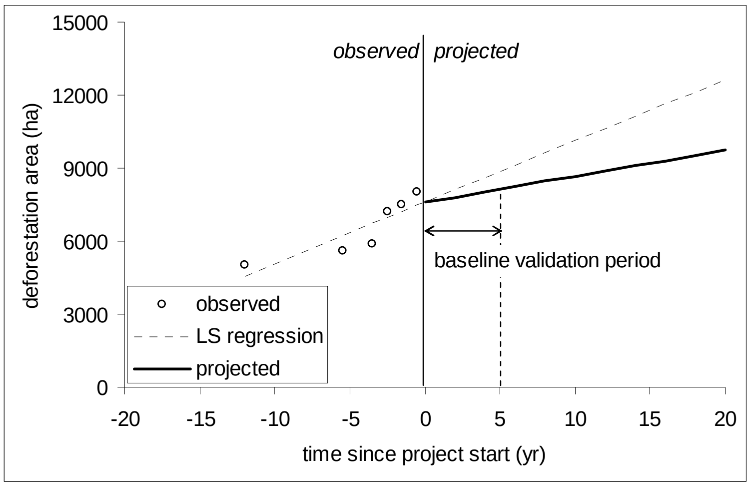
If the area of **deforestation/degradation is constant** (i.e. if the slope of the linear relationship between deforestation/degradation quantities and time is not significantly different from 0 at the 95% confidence level), a constant future deforestation/degradation quantity is assumed and is set as the mean of the observed deforestation/degradation amounts in the reference region, after discounting for uncertainty.

a = average of observed deforestation/degradation quantity
b = 0



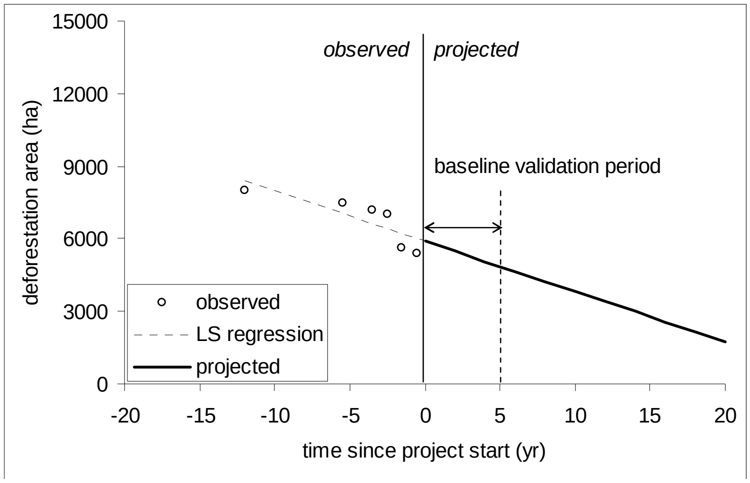
If the **deforestation/degradation quantity increases** (i.e. if the slope of the least squares linear regression between deforestation/degradation quantities and time is significantly larger than 0 at the 95% confidence level), the increase is (conservatively) set to be the lower 90% confidence interval of the least-square regression slope.

a = projected area at project start using least squares regression
b = lower 90% confidence interval of the least-square regression slope

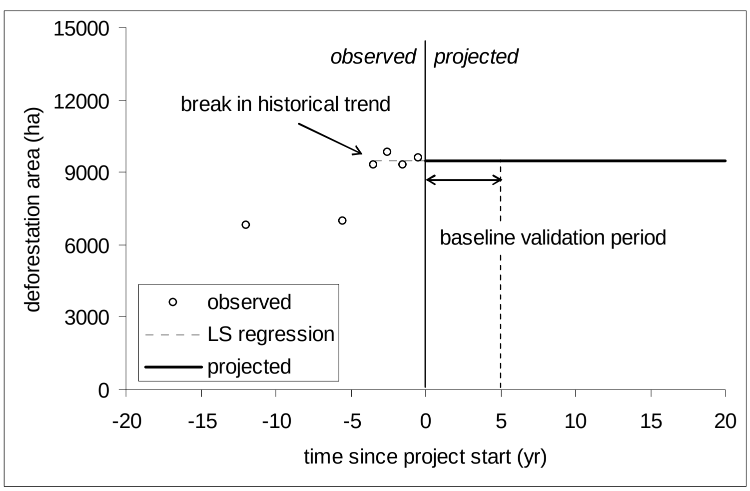


If the **deforestation/degradation quantity decreases** (i.e. if the slope of the least squares linear regression between deforestation/degradation quantities and time is significantly smaller from 0 at the 95% confidence level), set the decrease to the slope of the least squares regression.

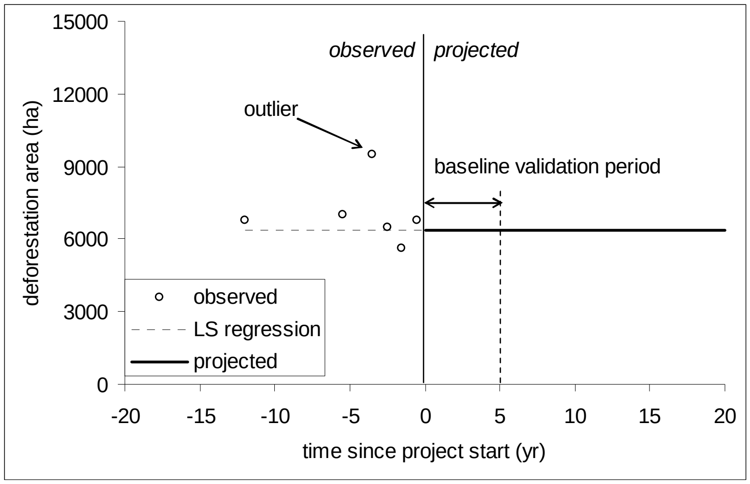
a = determined using least squares regression.
b = determined using least squares regression.



When there is a **clear break in the historical trend**, it is required to examine when the anomaly occurred, why it occurred, and whether the change is likely to be stable or not to determine whether to adjust the data points used in the least squares regression. A break in the historical trend shall only be considered when at least six points in time are available. A break in the historical trend usually indicates a technological breakthrough, a policy reform, or change in land use practice. If it is demonstrated that the reasons for a break in the trend continued into the future, omit the observations occurring before the break to project the future deforestation quantity. The projected deforestation rate must be determined from the period that goes back no farther than the appearance of the breakpoint (Sataye and Andrasko, 2007). Use one of the approaches above depending on the trend observed after the break.



Single outliers are most likely due to once-only anomalies (e.g., loss of forest land due to fire, hurricane or other natural disturbance). It is required that the cause of this single outlier be examined to determine if it may be removed. They may only be removed from the other points in the historical reference period if it is demonstrated that the occurrence of the outlier is due to specific conditions that are not present anymore (as would be the case for a natural disturbance). Use one of the approaches above depending on the trend observed after removing the outlier.



Once a_{DF},, b_{DF},, a_{DG}, and b_{DG} are determined, calculate the baseline total deforestation and degradation rates in the project area as:

$$D_{projectArea,baselineScenario,DF}(t) = (a_{DF} + b_{DF} \cdot t) \cdot \frac{size_{projectArea}}{size_{referenceRegion}} \quad (38)$$

$$D_{projectArea,baselineScenario,DG}(t) = (a_{DG} + b_{DG} \cdot t) \cdot \frac{size_{projectArea}}{size_{referenceRegion}} \quad (39)$$

where:

$D_{projectArea,baselineScenario,DF}(t)$, and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area for year t. [ha yr^{-1}]
a_{DF} and a_{DG}	=	Intercept of the linear relationship between time and deforestation/degradation rate. [ha yr^{-1}]
b_{DF} and b_{DG}	=	Slope of the linear relationship between time and deforestation/degradation rate. [ha yr^{-2}]
t	=	Time since project start (negative before project start). [yr]
$size_{projectArea}$	=	Total size of the project area. [ha]
$size_{referenceRegion}$	=	Total size of the reference region. [ha]

II.1.5.2 Step 5B – Calculate LULC Class or Forest Stratum-Specific Relative Reforestation and Regeneration Rates

Although reforestation is not allowed as a project activity under the VCS guidance, it must be accounted for under baseline conditions. Land may be out of forest cover for only a short time under baseline conditions, not accounting for transitions from non-forest to forest would therefore artificially increase the deforestation rates under baseline conditions and lead to an overestimation of NERs.

For every land class or forest stratum that transitions into a different class with higher biomass, calculate the relative regeneration or reforestation rate by dividing the area of the transition by the area of the "from" class:

for every transition for which $C(CS_2) > C(CS_1)$:

$$RFRGrate(CS_1 \rightarrow CS2) = \frac{\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)}{area_{historical}(CS_1, t_1) \cdot (t_2 - t_1)} \tag{40}$$

where:

$C(CS_1)$ and $C(CS_2)$	=	Carbon stock density of class or stratum 1 and 2, respectively. [MT C ha^{-1}]
$RFRGrate(CS_1 \rightarrow CS_2)$	=	Relative annual reforestation and regeneration rate for the transition from class or stratum 1 to 2. [ha yr^{-1}]
$\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)$	=	Area of transition from class or stratum 1 to 2 from time 1 to 2 during the historical reference period. [ha]
$area_{historical}(CS_1, t_1)$	=	Total area of class or stratum 1 during time 1. [ha]
t_1 and t_2	=	Time 1 and time 2, respectively. [years]

Calculate the LULC class or forest stratum-specific regeneration or reforestation rates for every pair of subsequent images in the historical reference period, and report the averages in a table in the PD.

II.1.5.3 Step 5C – Calibrate and Validate a Spatial Model to Predict the Suitability for Deforestation and Degradation

It is assumed that deforestation and degradation do not occur randomly within the forest area, but preferentially at specific locations where predisposing factors are present (De Jong 2007). These factors are referred to as *spatial driver variables* and were identified in section II.1.3.4. Spatial driver variables may be static, such as slope or elevation, or non-static, such as distance to the nearest road, or forest density. In addition, they may be continuous, such as distance to the closest market, or categorical, such as soil type. Using data from the historical reference period, logistic regression models can be used to quantify the suitability of deforestation and degradation, given that the values of the spatial driver variables are validated (Lambin 1997, Verburg et al. 2004 and Boer et al. 2006). It has been shown previously that the modeled suitability from logistic regression maps corresponds with actual future land-use changes. For example, Serneels and Lambin (2001) used the logistic model to identify the drivers of conversion to agriculture in Narok District, Kenya, and Williams et al. (2005) employed logistic regression models to understand the drivers of decline of native grasslands in Australia. To calculate a map of the suitability for deforestation and forest degradation, respectively, the following steps are to be followed once to create the deforestation model and once for the degradation model

1. For each pair of two subsequent images**, randomly select a large amount of forested grid-cells/pixels** from the first image. Use the second image of the pair to determine whether these grid-cells/pixels were deforested, degraded, or showed no change during the period in between the two images. Ensure grid-cells are selected at degrading, deforested, and no-change areas.
2. Calculate the **value of each spatial driver variable** based on the first LULC map of the image pair for each of the points selected in the previous step. Create a list containing the location, land transition category, and all values of each of the spatial driver variable. In case of non-static spatial driver variables, use a spatial driver at the time the first image was recorded. Deforestation and degradation usually occur in a clustered fashion. Therefore, include the distance to the forest edge, or forest fragmentation as spatial driver variables (Lambin et al., 1997).
3. Split this list randomly into a **calibration dataset and a validation dataset.** The calibration data will be used to fit the deforestation and degradation logistic regression models and the validation data will be used to independently assess the quality of the model. As a rule of thumb, the 2/3 of the points should be used for calibration and 1/3 for validation.
4. **Calibrate a logistic regression model for deforestation** based on the spatial driver variables. This model predicts the suitability for deforestation for every location in the project area. If necessary, apply mathematical transformations to make the effect of the spatial driver variables linear. For instance, the influence of a road on deforestation will decrease exponentially with distance to the road, and a log-transformation should be applied,
5. **Calibrate a logistic regression model for degradation** based on the spatial driver variables.
6. **Calibrate a logistic regression model for the LULC class of the new land use on cells selected for deforestation.** In case that there are more than two potential new LULC classes, use a multinomial logit model.
7. **Validate the logistic regression models**. Predict the new LULC categories for the validation data, and compare with the measured data.

II.1.5.4 Step 5D – Calculate All Class or Stratum-Specific Transition Rates.

Once the logistic regression models for deforestation and forest degradation, and the carbon density map are prepared, a simple cellular automata type model can be used to predict the future land use and land cover in each grid-cell and for each year of the crediting period. A similar approach, the combination of a logistic regression model with a cellular automata model is used by Echeverria et al. (2008) to elucidate which spatial driving variables led to forest fragmentation in southern Chile. This methodology employs a similar model as the GEOMOD model used by the latter authors, but with expanded transitions and land states. However, the model used in this methodology shares the following principles with the GEOMOD model (Pontius, 2006).

- **Neighborhood constraint.** Deforestation and forest degradation occur preferentially near already deforested land. Grid-cells that are within a certain distance to forest boundary will be preferentially deforested and degraded. This is incorporated by including the distance to the forest boundary as a spatial driver variable in the logistic regression model (see previous section).
- **Land suitability.** The logistic regression model calibrated in the previous section quantifies the suitability of a cell for deforestation and degradation. Deforestation and forest degradation is assigned first on land with the highest suitability.

Figure 5 outlines the steps followed by the land use change model.

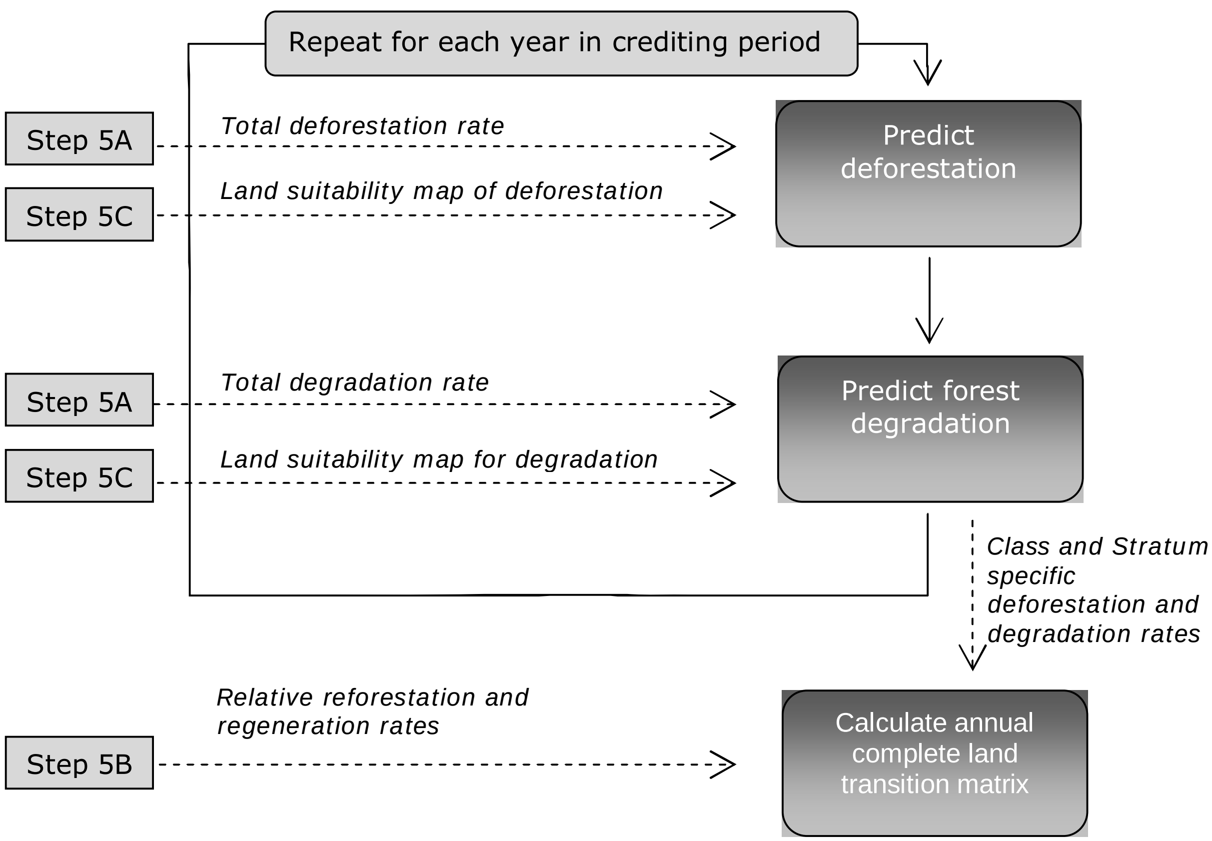


Figure 5. Outline of the procedure to calculate all land transitions

The following steps are followed for each year of the modeling period

1. Calculate the deforestation suitability for all forest cells using the logistic regression model.

2. Sort the forest cells according to their deforestation suitability from highest suitability to lowest suitability.
3. Start deforesting cells until the maximal deforestation amount based on the linear regression analysis in section II.1.5.1 is attained or the suitability value of the last deforested cell is below the land scarcity threshold $p_{\mathrm{DF,max}}$. Once the suitability is below this threshold, reduce the maximal deforestation amount by multiplying it with a "deforestation reduction factor" (Figure 6). Continue deforesting cells in order of decreasing suitability until the deforestation suitability drops below $p_{\mathrm{DG,min}}$. At that point, no further deforestation will take place.

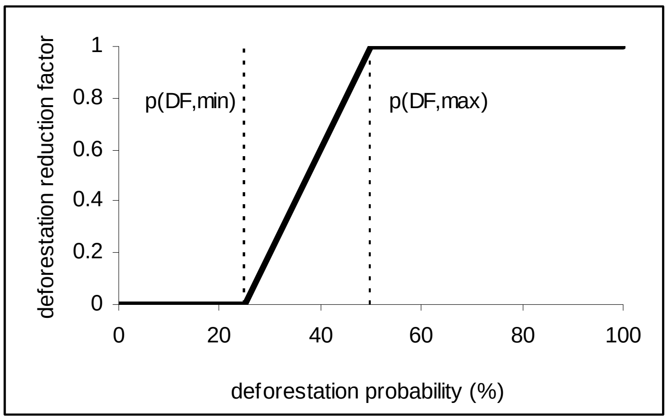


Figure 6. Effect of the deforestation probability (suitability) on the deforestation rate.

4. Calculate the suitability for a new non-forest LULC class on the cells that were selected for deforestation. Assign the LULC class with the highest suitability, according to the models calibrated in II.1.5.2, step B.
5. Repeat steps 1-3 for forest degradation on the forest cells that were not assigned for deforestation, and that are not in the forest strata or LULC class with the lowest carbon density. Degrade the cells selected for degradation by assigning them to the next-lower forest strata.
6. **For the area without ANR**, sum the areas for all transitions from the maps developed in the previous steps. Calculate the regeneration transitions from class or stratum 1 to 2 by multiplying the total area of class or stratum 1 with the relative regeneration rate for transitions from class or stratum 1 to 2.

$$\Delta area(t, classStratum1 \rightarrow classStratum = RFRGrate(classStratum1 \rightarrow classStratum2) \cdot area(t, classStratum1) \quad (41)$$

where:

$\Delta area(t, classStratum1 \rightarrow classStratum2)$	=	Area of transition from class or stratum 1 to 2 from time t to $t+1$. [ha]

$RFRGrate(classStratum1 \rightarrow classStratum2)$	=	Relative annual regeneration rate for the transition from class or stratum 1 to 2 from time t to $t+1$. [ha yr^{-1}]
$area(t, classStratum1)$	=	Total area of class or stratum 1 for time t of the crediting period. [ha]

All required values of $\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$ have now been calculated or year t.

For the area with ANR, only sum the areas for the transitions between forest and non-forest classes, see section II.2.4.2. These are the only required values for $\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$ for year t.

Reporting Requirements in the PD	PD section
1. Description of the approach followed to calculate the regression parameters in the calculation of the future deforestation and degradation rates. Justify the omission of outliers or the assumption of a break in the historical deforestation trend (if relevant). (see Step 5A)	2.4
2. Table with all relevant LULC class or forest stratum specific regeneration and reforestation rates, averaged over every pair of subsequent images. (see Step 5B)	2.4
3. Validation report of the logistic regression models with independent data. (see Step 5C)	2.4
4. A table with all land transitions under the baseline scenario separately for the area with and without ANR for every year through the crediting period according to the procedure in step 5D. For an example of such a table, see Table 18 in section II.4.1).	4.2

II.2 *Ex-ante* Estimation of GHG Emissions and Changes in Sinks under the Project Scenario inside the Project Area

II.2.1 Step 6 – Identify Project Activities and Estimate Total Deforestation and Degradation Rates under the Project Scenario

At least some or all of the deforestation drivers outlined in step 3 (section II.1.3) must be mitigated through specific project activities. Some activities may focus on increasing the livelihood options of local communities or prevention of leakage through e.g. increasing the land use intensity of already deforested land. The distinction between true REDD project activities and leakage prevention activities is often ambiguous within the context of mosaic deforestation, as any increase in livelihood of local communities will likely reduce deforestation and forest degradation both inside and outside of the project area. Therefore, leakage prevention activities are not considered separately in this section but treated as project activities.

The *ex-ante* estimation of the deforestation and forest degradation rates are based on a breakdown of the effectiveness of every project activity a in decreasing any deforestation driver d relative to that driver's contribution to deforestation and forest degradation, i.e. $effectiveness(a, d)$. For example, assume that the collection of fuel-wood leads to a degradation of 200 Mg C per year, and the introduction of fuel-efficient woodstoves decreases the emissions by 50 Mg C per year, and the development of biogas plants reduce the emissions by 100 Mg C per year. The effectiveness of fuel-efficient woodstoves to decrease degradation from fuel-wood collection $effectiveness(fuel\text{-}efficient\ stoves, fuel\text{-}wood\ collection)$ is 25%, whereas the effectiveness of biogas plants to reduce the degradation from fuel-wood collection is $effectiveness(fuel\text{-}efficient\ stoves, fuel\text{-}wood\ collection)$ is 50%. The values of the effectiveness must be estimated for every combination of project activities and drivers of deforestation and forest degradation. Note that the effectiveness values are only meant for *ex-ante* estimates of emission reductions. No actual *ex-post* VCUs are issued based on these values. The effectiveness values are often challenging to quantify, and depend on local conditions and the experience of the project proponent. However, the prediction of the volume of VCUs that a project will deliver crucially depends on the ability of the project proponents to predict effectiveness and refine these predictions through project monitoring.

Note that $effectiveness(a, d)$ should be interpreted as the maximal effectiveness, when all project conditions, such as adequate funding, the project's capacity, or the experience of the local communities, are optimal. Further in the text, it is explained how this maximal effectiveness is scaled down using a time-dependent factor for every project activity, i.e., $rate(a, t)$, to reflect that project activities will increase in effectiveness after a training period, or that project funding may be allocated in a phased manner.

The section below describes specific REDD project activities. Each activity description is followed by a table which outlines the procedure to quantify the maximal effectiveness for this project activity and each of the targeted drivers.

- **Strengthening the land-tenure status**.

  Legal agreements between the participating communities, landowners, project developers and the relevant government administrative levels are the necessary first step to protect the land. These legal agreements are particularly important when participating communities do not legally own the forest land, and the land-tenure status is unclear or obscured by a complex administrative hierarchy. The project proponents can assist local communities in securing their land tenure status. This can include developing legally binding community forestry agreements, purchasing or securing long-term conservation easements, or the revision of spatial plans and zoning laws. The establishment of these agreements will often require funds, which can be covered by the benefits from carbon trading. Strengthening the land-tenure status is essential to protect the land from encroachment by people other than participating communities and provide clarity on the allowed land use by the participating communities. Obviously, a legal protection of the land is not sufficient for a sound protection of the forest land. It must be complemented with an effective protection, social fencing, or patrolling system.

Target driver	*Maximal effectiveness quantification*	
Illegal logging of timber for commercial on-sale	$effectiveness < 5\%$ Legal recognition of the land-tenure status is a necessary but insufficient step in reducing deforestation, and usually does not directly lead to a reduction in deforestation.	(42)
Conversion of forest land to crop-land (by people other than participating communities)	$effectiveness < 5\%$ Id.	(43)
Conversion of forest land to settlements (by people other than participating communities)	$effectiveness < 5\%$ Id.	(44)

- **Development of sustainable forest and land use management plans.**

  Forest and land use management plans should be established in a participatory and democratic way. These plans can include the volumes of timber, fuel-wood or NTFP each community can sustainably harvest, the areas of livestock grazing, or the area of forest land that can be converted into settlements or cropland, and where the conversion must take place. The management plans must be based on current and future need for forest products and land. Such plans will increase the efficiency of the current land use and avoid the random conversion of forest patches which can accelerate forest degradation. The plans must be integrated and compatible with the land tenure and use rights. The plans must be long-term or permanent (where possible) in nature.

  The management plan is only binding for participating communities and will not affect the drivers of deforestation for which the agents are not participating in the project. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Conversion of forest land to crop-land by participating communities	$$effectiveness = \frac{\Delta area_{cropland,planned}}{\Delta area_{cropland,baseline}} \quad (45)$$ Forest and land-use plans usually explicitly indicate how much land can be converted from forest to crop-land. The baseline conversion rates must be estimated based on (in order of preference) (1) remote sensing analysis, (2) participatory rural appraisals.
Conversion of forest land to settlements by participating communities	$$effectiveness = \frac{\Delta area_{settlement,planned}}{\Delta area_{settlement,baseline}} \quad (46)$$ Id.
Logging of timber for local and domestic use by participating communities	$$effectiveness = \frac{H_{domestic,planned}}{H_{domestic}} \quad (47)$$ The baseline harvesting rate comes from (1) recent reports and studies within the project area, (2) peer-reviewed literature in regions similar to the reference region, (3) expert opinion.

- **Demarcating boundaries**

  The installation of fences, gates, boundary poles, and signage provides local communities a transparent, recognizable and fixed boundary of the project area. Because legal protection alone (project action 1, "Strengthening the land-tenure status") may be insufficient to prevent deforestation; often a physical boundary or signage is required to avoid deforestation, and support social fencing and patrolling. The boundaries of the discrete project area parcels must be clearly demarcated to be recognized by potential trespassers of the forest (hunters, illegal loggers, or other encroachers). The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Illegal logging of timber for commercial on-sale	$$effectiveness < 10\% \quad (48)$$ Demarcating boundaries does directly lead to only a minimal reduction in deforestation without patrolling or social fencing. This action is required but not sufficient for reductions in deforestation or forest degradation.
Conversion of forest land to crop-land by other people than participating communities	$$effectiveness < 10\% \quad (49)$$ Demarcating boundaries does directly lead to only a minimal reduction in encroachment without patrolling or social fencing. This action is required but not sufficient for reductions in deforestation or forest degradation.
Conversion of forest land to settlements by other people than participating communities	$$effectiveness < 10\% \quad (50)$$ Demarcating boundaries does directly lead to only a minimal reduction in conversion to settlements without patrolling or social fencing. This action is required but not sufficient for reductions in deforestation or forest degradation.

- **Protection, social fencing, and patrolling of boundaries.**

  The boundaries of the forest must be protected and patrolled. Often, there is a lack of official law enforcers to do this task, while communities are committed to defend their land-tenure and land use rights. Communities can be engaged in the regular patrolling of the forest area. It must be clarified with the local administration which actions can be taken in case of illegal trespassing (e.g., confiscating chainsaws, alerting local law enforcers, etc.). Improve synergies among local communities, law enforcement and other relevant agencies to support boundary protection. Other project actions include the creation of logistical plans to protect boundaries, social fencing, and the acquisition of equipment (e.g., small motorized vehicles) for patrolling and enforcement. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Illegal logging of timber for commercial on-sale	$$50\% < effectiveness < 90\% \qquad (51)$$ Patrolling and social fencing can be very effective in reducing illegal trespassing of the land. Set the value of effectiveness between the thresholds above based on (1) pilot experiments in the project area, (2) peer-reviewed studies in a similar area as the project area, or (3) advice from experts.
Conversion of forest land to crop-land by other people than participating communities	$$50\% < effectiveness < 90\% \qquad (52)$$ Violations of a stakeholder-approved management plan can be effectively minimized by forest patrolling and social control. Set the value of effectiveness between the thresholds above based on (1) pilot experiments in the project area, (2) peer-reviewed studies in a similar area as the project area, or (3) advice from experts.
Conversion of forest land to settlements by other people than participating communities	$$50\% < effectiveness < 90\% \qquad (53)$$ Violations of a stakeholder-approved management plan can be effectively minimized by forest patrolling and social control. Set the value of effectiveness between the thresholds above based on (1) pilot experiments in the project area, (2) peer-reviewed studies in a similar area as the project area, or (3) advice from experts.

- **Fire prevention.**

  If human-induced fire is threatening the project's forest, specific fire prevention measures could be taken. These include (1) installation of fire breaks, (2) cleaning of the forest from dead wood that can act as fuel for fires, especially around regenerating and young secondary forests, and (3) discouraging or eliminating (if possible) fire-based hunting techniques. Saplings and small trees are particularly vulnerable to forest fires. If this requires cutting down trees, or removing dead wood, the loss of carbon should be accounted for. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Human-induced forest fires	$$40\% < effectiveness < 60\% \quad (54)$$ Fire prevention measures such as fire breaks together with education can effectively reduce fire-related deforestation and forest degradation with 50%. Set the value of effectiveness between the thresholds above based on (1) pilot experiments in the project area, (2) peer-reviewed studies in a similar area as the project area, or (3) advice from experts.

- **Providing alternative livelihoods to the agents of deforestation**.

  If deforestation agents can engage in alternative livelihoods that are not based on deforestation, they can secure their income without the need to further clear forests.

  - As many as possible of the planned project activities should be **carried out by the local communities.** Engaging communities in forest patrolling, biomass inventory, fire prevention activities, installation of fences and boundary poles, and assisted natural regeneration activities. These activities will provide employment and a greater financial return flowing to the communities. In addition, the active involvement of the local communities will strengthen the project goals and decrease the risks of project failure.
  - Part of the forest can be made accessible for sustainable **eco-tourism**, which will create jobs and increase revenue.
  - The sustainable extraction of **non-timber forest products** can be further developed and commercialized. This includes the harvesting of honey, medicinal plants, fungi, and the extraction of resins. Clear harvesting plans need to be developed to ensure the sustainable extraction of these commodities.

  It is assumed that people will shift automatically towards a livelihood alternative that has a sufficiently greater return than their current livelihood. Therefore, the total effectiveness is calculated by dividing the income from alternative livelihoods by the total value of forest products that are harvested from the forest and sold on local markets. It is further assumed that alternative livelihood options must be 25% more economically attractive before people will switch to the alternative livelihoods. The total effectiveness thus becomes $0.75 \cdot \frac{(income\ through\ alternative\ livelihood)}{(total\ value\ of\ forest\ products)}$. This total effectiveness is then divided into individual values for the effectiveness for each of the different target drivers by multiplying with the respective relative financial contribution of the target driver to the total value of forest products. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	Maximal effectiveness quantification
Conversion of forest land to crop-land for crops that are sold on market	$effectiveness = 0.75 \cdot \frac{(income\ through\ alternative\ livelihood) \cdot (value\ \ of\ crops\ sold)}{(total\ value\ of\ forest\ products)^2}$ (55)
Illegal logging of timber for sale by participating communities	$effectiveness = 0.75 \cdot \frac{(income\ through\ alternative\ livelihood) \cdot (value\ \ of\ timber\ sold)}{(total\ value\ of\ forest\ products)^2}$ (56) The "$value\ \ of\ timber\ sold$" parameter can be estimated by multiplying $H_{illegal}$ with the price for timber on the market.
Collection of fuel-wood and charcoal production for sale on markets	$effectiveness = 0.75 \cdot \frac{(income\ through\ alternative\ livelihood) \cdot (value\ \ of\ fuel\text{-}wood\ sold)}{(total\ value\ of\ forest\ products)^2}$ (57)

- **Intensification of agriculture.**

  Forest land is often deforested to make place for subsistence farming. Project activities that will increase productivity and agricultural yields on existing cropland and animal stocking rates on grazing lands minimize the need for further forest clearing. Such activities include increases in mechanization, installation of irrigation systems, increases in fertilizer use, the introduction of high-yielding crop varieties, and increase in livestock stocking rates. Only sustainable farming techniques should be promoted and any increases in GHG emissions due to these activities must be monitored, reported, and accounted for. Agriculture can be intensified through (1) sponsoring pilot and demonstration studies on sustainable agriculture and agro-forestry, (2) strengthening the relations with local agricultural extension services, colleges and universities, (3) establishing a system of small grants or micro-financing for local farmers to invest into agricultural equipment, infrastructure, seeds, or fertilizer. The adoption rate of the practices should be duly monitored to account for increases in GHG emissions.

  Intensification measures must be done on land that was already under agriculture or on land that is sanctioned to become agricultural land given the land-use plans. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Conversion of forest land to crop-land by project proponents	$$effectiveness = (maximal\ adoption\ rate) \cdot (increase\ in\ yield\ per\ hectare) \quad (58$$ Estimate the maximal adoption rate based on the willingness of project participants to change their practices from (in order of preference): (1) quantified in participatory rural appraisals, or (2) expert opinion. Estimate the relative increase in yield from (1) field studies, (2) peer-reviewed literature, or (3) local agricultural extension experts.

- **Decrease the consumption of fuel-wood.**

  The collection of fuel-wood only leads to forest degradation if it is collected from live trees. A low-intensity collection of fuel-wood from downed dead wood may in fact have a positive effect on forest regeneration by decreasing the potential for forest fires. In cases where the collection of fuel-wood leads to forest degradation, the introduction of fuel-efficient wood-stoves or propane stoves will decrease the need for local consumption fuel-wood (Top et al., 2004). Adoption rates of these alternatives need to be monitored, together with the potential on-sale of fuel-wood on local markets, which can potentially annul the GHG benefits generated by the alternative stoves. Only fuel-wood gathering for domestic use is allowed in project areas at a rate that is lower than the baseline fuel-wood gathering rate taking into account the expected population growth. No on-sale of fuel-wood gathered in project areas is allowed. The following table outlines the procedure to quantify the maximal effectiveness for this driver.

Target driver	*Maximal effectiveness quantification*
Fuel-wood collection or charcoal production	$$effectiveness = (maximal\ adoption\ rate) \cdot (increase\ in\ efficiency\ of\ stoves) \quad (59)$$ Estimate the maximal adoption rate based on the willingness of project participants to change their practices as (1) quantified in participatory rural appraisals or (2) expert opinion. Estimate the relative increase in efficiency of stoves from (1) field studies, (2) peer-reviewed literature, or (3) local experts.

The success of the implementation and on-going maintenance of these activities is critically dependent on the active involvement of all stakeholders in the planning and execution of these project activities. In particular, the local communities must be actively involved. Therefore, project management, advisory, oversight and consultative structures shall be developed to ensure an active involvement of all stakeholders. Through consultation with stakeholders, a transparent mechanism shall be set-up to ensure the equitable distribution of benefits from carbon benefits from the project.

A holistic approach should be taken towards meeting the various resource needs of local communities. For example, rather than excluding local communities from using any forest resources at all (and therefore necessarily forcing them to acquire these resources outside of the project area or purchase these on local or provincial markets, leading to outsource leakage), a sustainable (agro-)forestry management plan should be put in place that can meet local wood and agricultural needs.

The effectiveness of project actions may change during the crediting period, due to increased experience of project implementers or an increased allocation of funds during the crediting period. This time-dependent project activity rate is accounted for by integrating a factor $rate(a,d)$ for project activity a during year t. As was mentioned before, $effectiveness(a,d)$ thus represents the maximally attainable effectiveness given project conditions and capacity is optimal. As a consequence, $rate(a,d)$ must be 100% at least 1 year during the crediting period. The relative reduction in deforestation can be estimated *ex-ante* by integrating the relative proportion of each of the deforestation drivers with the effectiveness coefficients and the estimated adoption rates for each of the project activities.

$$RelativeDriverImpact_{DF}(t,d) = \sum_{a=1}^{nrActivities} \left(rate(a,t) \cdot effectiveness(a,d) \cdot contribution_{DF}(d) \right) \quad (60)$$

$$RelativeDriverImpact_{DG}(t,d) = \sum_{a=1}^{nrActivities} \left(rate(a,t) \cdot effectiveness(a,d) \cdot contribution_{DG}(d) \right) \quad (61)$$

$$RelativeProjectImpact_{DF}(t) = \sum_{d=1}^{nrDrivers} RelativeDriverImpact_{DF}(t,d) \quad (62)$$

$$RelativeProjectImpact_{DG}(t) = \sum_{d=1}^{nrDrivers} RelativeDriverImpact_{DF}(t,d) \quad (63)$$

where:

$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DG}(t,d)$	=	Relative impact of a driver d on deforestation and forest degradation, respectively for year t of the crediting period. [-]
$RelativeProjectImpact_{DF}(t)$ and $RelativeProjectImpact_{DG}(t)$	=	Impact of all project activities on deforestation and forest degradation respectively, relative to the baseline deforestation and forest degradation rates during year t. [-]
$nrActivities$	=	Total number of project activities. [-]
$nrDrivers$	=	Total number of deforestation drivers. [-]
$rate(a,t)$	=	Adoption rate or relative degree of activity for activity a during year t. A value of 100% indicates that the activity cannot be more efficient in reducing deforestation or forest degradation. [-]

$effectiveness(a,d)$	=	The effectiveness of project action a to reduce deforestation driver d. [-]
$contribution_{DF}(d)$ and $contribution_{DG}(d)$	=	The relative importance of driver d in deforestation/degradation to the total /degradation. [-]

The absolute rate of deforestation in hectares per year in the project region under the project scenario can be calculated by multiplying the relative project impact with the total deforestation and forest degradation rates in the project region under the baseline scenario.

$$D_{projectArea,projectScenario,DF}(t) = RelativeProjectImpact_{DF}(t) \cdot D_{projectArea,baselineScenario,DF}(t) \quad (64)$$

$$D_{projectArea,projectScenario,DG}(t) = RelativeProjectImpact_{DG}(t) \cdot D_{projectArea,baselineScenario,DG}(t) \quad (65)$$

where:

$D_{projectArea,projectScenario,DF}(t)$ and $D_{projectArea,projectScenario,DG}(t)$	=	Rate of deforestation/degradation within the project area for year t under the project scenario. [ha yr^{-1}]
$RelativeProjectImpact_{DF}(t)$ and $RelativeProjectImpact_{DG}(t)$	=	Relative impact of all project activities on deforestation and forest degradation respectively during year t. [-]
$D_{projectArea,baselineScenario,DF}(t)$ and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area for year t. [ha yr^{-1}]

II.2.2 Step 7 – Calculate Forest Strata-Specific Deforestation and Degradation Rates

Use the LULC model calibrated and validated in section in II.1.5 to divide the total *ex-ante* deforestation and forest degradation rates under the project scenario into individual rates for every forest stratum transition. The same logistic regression models may be used for calculating the stratum-specific rates under the project scenario. For every year of the crediting period, present a land transition table for the project areas under the project scenario similar to Table 18 in the projected land use change summary of section II.4.1.

Reporting Requirements in the PD	PD section
1. For every planned project activity:	2.4
a. Description of the activity, including which agents and drivers of deforestation are targeted.	1.8
b. Map of the planned location of the activities (if relevant).	1.8
c. Analysis of the labor/hours needed for the activity and who will implement.	1.9
d. Indication on how the involvement of all stakeholders and community levels will be ensured.	6
e. All risks involved in why the project activities may fail.	1.11
f. Estimate of the adoption rate $rate(a,t)$ per year t of the project activity.	1.9
g. A summary table of the effectiveness $effectiveness(a,d)$ for every action a and driver d. This quantity describes the impact of a project action on a targeted driver. Include a justification of the selection of an effectiveness factor based on data from the literature, pilot studies, or participatory social appraisal studies. Specify all underlying assumptions.	1.9
2. Table of $RelativeProjectImpact_{DF}(t)$ and $RelativeProjectImpact_{DF}(t)$ for every year t of the crediting period. This quantity is the relative reduction in the total amount of degradation and deforestation for every year of the crediting period.	2.4
3. Table with $D_{projectArea,projectScenario,DF}(t)$, the estimated total deforestation rate in the project area and $D_{projectArea,projectScenario,DG}(t)$, the estimated total forest degradation rate in the project area.	2.4
4. Land transition table under the project scenario for the project area for every year of the next crediting period (see Table 18 in section II.4.1).	4.3

II.2.3 Step 8 – Estimate GHG Emissions Sources

Project activities may lead to an increase in emissions in the project area, which are not related to carbon pools, named "emission sources". This should be accounted for, and subtracted from the carbon pool-related emission reductions generated by the project activities. The emission sources from project activities within the project area can be calculated as:

$$E_{sources,projectArea} = E_{fencing} + E_{vehicle} + E_{fireBreaks} \tag{66}$$

where:

$E_{sources,projectArea}$ = Emission sources from project activities within the forests of the project area. [MTCO2e yr^{-1}]

$E_{fencing}$ = Annual GHG emissions from boundary poles and fencing. [MTCO2e yr^{-1}]

$E_{vehicle}$	=	Annual GHG emissions from fuel use for vehicles used for implementation of REDD project activities (e.g., patrolling, transportation of materials and laborers, machinery to implement assisted natural regeneration activities). [MTCO2e yr^{-1}]
$E_{fireBreaks}$	=	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. [MTCO2e yr^{-1}]

The significance of these and other emissions is tested according to the methodology provided in EB31 appendix 16 to determine whether it must be included (see section II.4.1). If an emission source is found insignificant, it may be omitted.

II.2.3.1 Step 8A – Estimate GHG Emissions from Boundary Poles and Fencing ($E_{fencing}$)

The demarcation of protected forests and the fencing of plots under assisted natural regeneration and enrichment planting to protect these from animal grazing and fuel-wood collection may require fencing using wooden posts. If the source of the wood posts is not renewable (e.g., the production of posts leads to deforestation), GHG emissions will occur.

The supply source of the posts used for fencing must be specified in the PD. If the outside source used is not renewable, emissions due to use of wood posts for fencing must be included in the calculation of emissions sources. The approached applied in this methodology is based on the accepted CDM methodology AR-AM0003 version 3. Emissions from fence posts can be estimated as follows:

$$E_{fencing} = \frac{44}{12} \cdot NRP \cdot FNRP \cdot APV \cdot \rho_{wood} \cdot BEF_2 \cdot CF \qquad (67)$$

where:

$E_{fencing}$	=	Annual GHG emissions from boundary poles and fencing. [MTCO2e yr^{-1}]
NRP	=	Number of fence posts installed per year. If not available, estimate this by dividing the total project perimeter by the average distance between wood posts from field observations. [yr^{-1}]
$FNRP$	=	Fraction of posts from off-site non-renewable sources. [-]
APV	=	Average volume of per wood posts (estimated from sampling). [m^3]
ρ_{wood}	=	Average basic wood density. See IPCC GPG-LULUCF 2003 Table 3A.1.9. [Mg m^{-3}]
BEF_2	=	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass including bark. See IPCC GPG-LULUCF 2003 Table 3A.1.10. [-]
CF	=	Carbon fraction of dry matter (default = 0.5). [-]

Add annual values of $E_{fencing}$ to the summary table of all GHG emissions due to project activities (Table 19).

II.2.3.2 Step 8B – Estimate GHG Emissions from Fuel Used for Vehicles ($E_{vehicle}$)

The GHGs emitted by vehicles used for the forest biomass inventory, silvicultural activities, and patrolling must be subtracted from GHG emission reductions of the project. Therefore, project participants shall make an estimate of yearly fuel consumption taking into account travel distances, vehicle/machine fuel efficiency, machine hours, and timing of planting and harvesting. For each estimate, the assumptions must be documented and, where possible, supported by past practices.

The GHG emissions from fuel use of vehicles can be estimated as following (following IPCC GPG 2006 guidelines for National GHG Inventories, Vol. 2. – Energy, Equation 3.2.1):

$$E_{vehicle} = \sum_{i=1}^{nrFuel} FC(i) \cdot \rho_{fuel}(i) \cdot \frac{NCV(i)}{10^6} \cdot EF_{fuel,CO2}(i) \quad (68)$$

where:

$E_{vehicle}$	=	GHG emissions from fuel use for vehicles used for implementation of REDD project activities vehicles. [MTCO2e yr^{-1}]
$nrFuel$	=	Number of fuel types used (diesel, gasoline, natural gas, propane, etc.). [-]
i	=	Fuel type
$FC(i)$	=	Estimated annual consumption of fuel type i [liters yr^{-1}]. In case of vehicles, this can be estimated by multiplying the distance traveled [km] by the fuel efficiency of the vehicle. [l km^{-1}]
$\rho_{fuel}(i)$	=	Standard density of fuel i. Use standard values of 0.737 kg l^{-1} for gasoline and 0.85 kg l^{-1} for diesel fuel. [kg l^{-1}]
$NCV(i)$	=	Net caloric value of fuel i. Use values from IPCC GPG 2006 guidelines for Energy (Table 1.2), if no regional estimates are available. The most specific and conservative values should be used. [TJ Gg^{-1}]
$EF_{fuel,CO2}(i)$	=	CO_2 emission factor for fuel type i. Use values from IPCC GPG 2006 guidelines for Energy (Table 3.2.1), if no regional estimates are available. The most specific and conservative values should be used. [kg CO_2 Gg^{-1}]

Add annual values of $E_{vehicle}$ to the summary table of all GHG emissions due to project activities (Table 19)

II.2.3.3 Step 8C – Estimate GHG Emissions from Fire Breaks and Other Fire Prevention Measures ($E_{fireBreaks}$)

The carbon lost by removing trees or biomass for fire prevention measures such as fire breaks must be accounted for. This includes the project emissions from fire breaks cleared by cutting and removal by controlled burning. The emissions from fire breaks can be calculated by:

$$E_{fireBreaks} = \frac{44}{12} \cdot \sum_{i=1}^{nrFireClasses} area_{biomassLoss}(i) \cdot C(i) + \sum_{i=1}^{nrClasses} area_{fireBiomassLoss}(i) \cdot C(i) \left(\frac{44}{28} \cdot \frac{GWP_{N2O} \cdot ER_{N2O}}{r} + \frac{16}{12} \cdot GWP_{CH4} \cdot ER_{CH4} \right) \quad (69)$$

where:

$E_{fireBreaks}$	=	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. [MTCO2e yr^{-1}]
$nrFireClasses$	=	Number of forest strata in which fire breaks were installed. [-]
$area_{biomassLoss}(i)$	=	Total annual area of forest stratum i that was cleared. [ha yr^{-1}]
$C(i)$	=	Carbon content in forest stratum i. It is conservatively assumed that all biomass is removed. [Mg C ha^{-1} yr^{-1}].
$area_{fireBiomassLoss}(i)$	=	Annual area of forest stratum i that was cleared by controlled burning. [ha yr^{-1}]
GWP_{N2O}	=	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period. [-]
ER_{N2O}	=	Emission ratio for N_2O (IPCC default value = 0.007). See Table 3A.1.15 in IPCC GPG-LULUCF 2003. [-]
r	=	Carbon-to-Nitrogen ratio of the wood. If no (lower) values are available, this can be conservatively approximated as 100, based on leaf litter analyses. [-]
GWP_{CH4}	=	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period). [-]
ER_{CH4}	=	Emission ratio for CH_4 (IPCC default value = 0.012). See Table 3A.1.15 in IPCC GPG-LULUCF (2003). [-]

Add annual values of $E_{fireBreaks}$ to the summary table of all GHG emissions due to project activities (Table 19).

PD Reporting requirements	**PD section**
1. List of the assumptions, data sources, and other information relevant to the calculation of the emissions for every source.	2.5
2. Summary of all individual emissions in Table 19.	2.5

II.2.4 Step 9 – Estimate the Net GHG Sequestration from Assisted Natural Regeneration Activities

This methodology allows specific measures aimed at restoring degraded forest. These activities can consist of enrichment planting and specific silvicultural activities which will restore the forest, e.g. coppicing, thinning of dominant species, and are referred to as "assisted natural regeneration" (ANR) activities. Note that ANR activities can only be done on degraded forest land; the conversion of non-forest land into forest land is not allowed under this methodology. These ANR activities serve a triple goal: (1) increase the project area's overall GHG sink strength, (2) reduce activity-shifting, and (3) provide alternative livelihoods to local communities by employing local communities for executing the work. A detailed accounting of any increases in GHG emissions related to these activities is necessary.

A detailed management plan of the ANR activities must be included in the PD. The management plan must include all proposed ANR activities and their exact locations. Adjustment of the assisted natural regeneration management plans is allowed until the first verification. After the first verification, the management plan for ANR activities is fixed.

The calculation of the GHG removals by sinks due to assisted natural regeneration activities is based on the CDM methodology AR-ACM0001 version 3. Wherever possible in this section, notation from AR-ACM0001 version 3 was retained. Combining and annualizing equations (33), (12), (13), and (14) from AR-ACM0001 version 3 yields:

$$C_{ANR}(t) = \frac{44}{12} \cdot \Delta C_{ANR}(t) - E_{ANR,biomassLoss}(t) - \Delta C_{ANR,BSL}(t) - LK_{ANR}(t) - GHG_{E,ANR}(t) \qquad (70)$$

where:

$C_{ANR}(t)$	=	Net anthropogenic greenhouse gas removals due to biomass increase in assisted natural regeneration. [MTCO2e]
$\Delta C_{ANR}(t)$	=	Annual change in carbon stocks in all selected carbon pools due to ANR for year t. [Mg C yr^{-1}]
$E_{ANR,biomassLoss}(t)$	=	Increase in CO_2 emissions from loss of existing woody biomass due to site-preparation (including burning), and/or to competition from forest (or other vegetation) planted as part of the ANR activities. [MTCO2e]
$GHG_{E,ANR}(t)$	=	Increase in GHG emissions as a result of the implementation of the proposed ANR activities during year t. [MTCO2e]
$\Delta C_{ANR,BSL}(t)$	=	Baseline greenhouse gas emissions or sources for year t. [Mg C yr^{-1}]
$LK_{ANR}(t)$	=	Total GHG emissions due to leakage for year t. [Mg C yr^{-1}]

- The procedure for calculating $\Delta C_{ANR}(t)$ is explained in section II.2.4.1.
- The procedure for calculating $\Delta C_{BSL}(t)$ is explained in section II.2.4.2.

- Report the difference $\Delta C_{ANR}(t) - \Delta C_{ANR,BSL}(t)$ in column [6] of Table 20.
- The activity-shifting leakage from ANR activities is included in the total project's leakage, as explained in section II.3.
- The procedure for calculating $E_{ANR,biomassLoss}$ and $GHG_{ANR,E}(t)$ is explained in section II.2.4.3.

II.2.4.1 Step 9A – Estimate Carbon Stock Increase from Biomass

The procedure to calculate the carbon uptake by biomass due to assisted natural regeneration follows the CDM-approved methodology AR-ACM0001 version 3.

$$\Delta C_{ANR}(t) = \sum_{i=1}^{nrStrata} \Delta C(t,i) \quad (71)$$

where:

$\Delta C_{ANR}(t)$	=	Annual change in carbon stocks in all selected carbon pools due to ANR for year t during the crediting period. [Mg C yr^{-1}]
$nrStrata$	=	Number of forest strata. [-]
$\Delta C(t,i)$	=	Carbon stock change for ANR stratum i for year t during the crediting period. [Mg C yr^{-1}]

As stated earlier, $\Delta C(t,i)$ is the sum of aboveground and belowground tree biomass. Similarly as in AR-ACM0001 version 3, changes in dead wood under the project scenario must be conservatively omitted for *ex-ante* calculations. The aboveground and belowground tree biomass is calculated using the "allometric method" following Equation (22) in AR-ACM0001 version 3:

$$\Delta C(t,i) = area_{projectAreaWithANR,projectScenario}(t,i) \cdot \frac{C(t_2,i) - C(t_1,i)}{t_2 - t_1} \quad (72)$$

where:

$area_{projectAreaWithANR,projectScenario}(t,i)$	=	Amount of land on which ANR activities are planned under the baseline scenario for year t and in stratum i. [ha]
$C(t_2,i)$ and $C(t_1,i)$	=	Aboveground carbon stock density during years t_2 and t_1 respectively and in stratum i. [Mg DM ha^{-1}]
$t_2 - t_1$	=	Duration between times 1 and 2. [year]

Ex-ante, values for biomass densities must be based on pilot projects or data on biomass increases in regenerating forests from the literature. *Ex-post*, this quantity must to be monitored for actual biomass according to the procedures within this document (see section III.3.3).

II.2.4.2 Step 9B – Calculate Baseline Emissions or Sinks on Land on which Assisted Natural Regeneration Activities are Planned

Baseline emissions from land on which ANR activities are proposed are calculated analogously as for land without ANR activities except for the treatment of forest degradation and regeneration under the baseline scenario. To remain conservative, only the baseline scenario for ANR land only includes transitions between forest and non-forest LULC classes. In addition, regeneration under the baseline scenario is considered by using continuous "net annual increments" in Mg C ha^{-1} yr^{-1} which may be specific for the forest strata. This departure from the previous approach for land without ANR is necessary because (1) the combination of the discrete approach to account for changes in biomass by transitions among forest strata for the baseline and the continuous carbon accounting approach from AR-ACM0001 version 3 for the scenario will lead to unexpectedly discontinuous GHG benefits from ANR, (2) incases when forest degradation has been excluded due to low accuracy of remote sensing analysis, this procedure will still assume a baseline regeneration rate. The baseline emissions or sinks on land with ANR can be calculated using the following equation.

$$\Delta C_{ANR,BSL}(t) = \frac{44}{12} \cdot CF \cdot \sum_{i=1}^{nrANRStrata} NAI(i) \cdot area_{projectAreaWithANR,baselineScenario(t,i)} + \sum_{i=1}^{nrFNFtransitions} \left(u_{classification} \cdot \Delta area_{projectAreaWithANR,baselineScenario}(t,i) \cdot u_{inventory}(i) \cdot EF(i)\right) \quad (73)$$

where:

$\Delta C_{ANR,BSL}(t)$ = Baseline greenhouse gas emissions or sources for year t. [Mg C yr^{-1}]

CF = Carbon fraction of woody material (use a default value of 0.5). [Mg C $(Mg\ DM)^{-1}$]

$nrANRStrata$ = Number of strata within the project area on which ANR activities are proposed. [-]

$NAI(i)$ = Net annual increment due to natural regeneration and succession for the "from" class of transition i, as reported in section II.1.4.2. [Mg DM ha^{-1} yr^{-1}]

$area_{projectAreaWithANR,baselineScenario(t,i)}$ = Size of strata i within the project area on which ANR activities are proposed for year t under the baseline scenario. [ha]

$nrFNFtransitions$ = Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the "from" or the "to" classes are non-forests. [-]

$u_{classification}$ = Discounting factor for uncertainty of LULC classification. [-]

$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$	=	Hectares undergoing transition i within the ANR area under the baseline scenario for year t. [ha yr^{-1}]
$u_{inventory}(i)$	=	Discounting factor for uncertainty of biomass inventory related to transition i. [-]
$EF(i)$	=	Emission factor for transition i. [MTCO2e ha^{-1}]

II.2.4.3 Step 9C – Calculate Emission Sources from Assisted Natural Regeneration

Under this methodology, all emissions from the proposed ANR project activities, including, $GHG_E(t)$ and $E_{biomassLoss}(t)$, are combined in $E_{sources,ANR}$:

$$E_{sources,ANR}(t) = E_{biomassLoss,ANR}(t) + GHG_{E,ANR}(t) \quad (74)$$

where:

$E_{sources,ANR}(t)$	=	Emissions of sources from methane, nitrous oxide, fuel-CO_2 and biomass removal from ANR activities during year t. [MTCO2e]
$E_{biomassLoss,ANR}(t)$	=	Increase in CO_2 emissions from loss of existing woody biomass due to site preparation, and/or competition from forest (or other vegetation) planted as part of the ANR project activity. [MTCO2e]
$GHG_{E,ANR}(t)$	=	Increase in GHG emissions as a result of the implementation of the proposed ANR activity within the project boundary during year t. [MTCO2e]

- The **CO_2 emissions from loss of existing woody biomass** for land preparation, $E_{biomassLoss,ANR}(t)$, are calculated as following

$$E_{biomassLoss,ANR}(t) = \frac{44}{12} \cdot \sum_{i=1}^{nrANRstrata} area_{biomassLoss}(t,i) \cdot C(i) \quad (75)$$

where:

$E_{biomassLoss,ANR}(t)$	=	Increase in CO_2 emissions from loss of existing woody biomass due to site preparation, and/or competition from forest (or other vegetation) planted as part of the ANR project activity. [MTCO2e]
$nrANRstrata$	=	Number of strata within the project area on which ANR activities are proposed. [-]
$area_{biomassLoss}(t,i)$	=	Area of biomass removed within ANR stratum i during year t. [ha]

$\Delta C(i)$	=	Carbon content in ANR stratum i. To remain conservative, it is assume that all biomass is removed. [Mg C ha^{-1} yr^{-1}]

- The **increase in GHG emissions as a result of the implementation of the proposed ANR activity**, $GHG_{E,ANR}(t)$, can be broken down into two parts. Fuel used during the land preparation is already accounted for under project emissions, section II.2.3.2.

$$GHG_{E,ANR}(t) = E_{fire,ANR}(t) + E_{fertilization,ANR}(t) \quad (76)$$

where:

$E_{fire,ANR}(t)$	=	CH_4 and N_2O emissions of controlled burning of existing woody biomass for land preparation of assisted natural regeneration activities during year t. [MTCO$_2$e yr^{-1}]
$E_{fertilization,ANR}(t)$	=	GHG emission from fertilization for land preparation of assisted natural regeneration activities (e.g., to accelerate growth in the early development stages of the seedling) during year t. [MTCO$_2$e yr^{-1}]

- The CH_4 and N_2O emissions of burning of existing woody biomass for land preparation, $E_{fire,ANR}$, are calculated as following:

$$E_{fire,ANR} = \sum_{i=1}^{nrANRStrata} area_{fireBiomassLoss,ANR}(t,i) \cdot C(i) \cdot \left(\frac{44}{28} \cdot \frac{GWP_{N2O} \cdot ER_{N2O}}{r} + \frac{16}{12} \cdot GWP_{CH4} \cdot ER_{CH4}\right) \quad (77)$$

where:

$E_{fire,ANR}$	=	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. [MTCO2e yr^{-1}]
$nrANRStrata$	=	Number of strata within the project area on which ANR activities are proposed. [-]
$area_{fireBiomassLoss,ANR}(t,i)$	=	Area of biomass removed within ANR stratum i during year using controlled burning t. [ha]
$\Delta C(i)$	=	Carbon content in ANR stratum i. To remain conservative, it is assume that all biomass is removed. [Mg C ha^{-1} yr^{-1}]
GWP_{N2O}	=	Global Warming Potential for N_2O (IPCC default value = 310 for the first commitment period). [-]
ER_{N2O}	=	Emission ratio for N_2O (IPCC default value = 0.007). See Table 3A.1.15 in IPCC GPG-LULUCF 2003. [-]

r	=	Carbon-to-Nitrogen ratio of the wood. If no (lower) values are available, this can be conservatively approximated as 100, based on leaf litter analyses. [-]
GWP_{CH4}	=	Global Warming Potential for CH_4 (IPCC default value = 21 for the first commitment period). [-]
ER_{CH4}	=	Emission ratio for CH_4 (IPCC default value = 0.012). See Table 3A.1.15 in IPCC GPG-LULUCF (2003). [-]

- GHG emission from **fertilization during enrichment planting**, $E_{fertilization,ANR}(t)$, are calculated following Equation 3.2.18 in the 2003 IPCC GPG-LULUCF:

$$E_{fertilization,ANR}(t) = \frac{44}{28} \cdot GWP_{N2O} \cdot EF_{N\text{-}inputs} \cdot \left(N_{synthetic,ANR}(t) \cdot (1 - f_{GASF}) + N_{organic,ANR}(t) \cdot (1 - f_{GASM})\right) \tag{78}$$

where:

$E_{fertilization,ANR}(t)$	=	GHG emission from fertilization for land preparation of ANR activities during year t. [$MTCO_2e\ yr^{-1}$].
GWP_{N2O}	=	Global Warming Potential for N_2O (IPCC default = 310 for the first commitment period). [-]
$EF_{N\text{-}inputs}$	=	Emission factor for emissions from N inputs. Use the default emission factor of 1.25 % of applied N As noted in IPCC GPG 2000. [-]
$N_{synthetic,ANR}(t)$	=	Total amount of synthetic fertilizer for land preparation of ANR activities, adjusted for volatilization as NH_3 and NO_x during year t. [$Mg\ N\ ha^{-1}\ yr^{-1}$]
f_{GASF}	=	Fraction that volatilizes as NH_3 and NO_x for synthetic fertilizers. Use the default value for the fraction of synthetic fertilizer nitrogen that is emitted as NO_x and NH_3 of 0.1 as noted in the 1996 IPCC Guideline. [-]
$N_{organic,ANR}(t)$	=	Total amount of organic fertilizer for land preparation of ANR activities during year t. [$Mg\ N\ ha^{-1}\ yr^{-1}$]
f_{GASM}	=	Fraction that volatilizes as NH_3 and NO_x for organic fertilizers. The default values for the fractions of organic fertilizer nitrogen that is emitted as NO_x and NH_3 is 0.2 in the 1996 IPCC Guideline. [-]

Reporting Requirements in the PD	PD section
1. Estimates of biomass increases due to assisted natural regeneration activities based on literature data. Include the source, the methodology used, whether all species were included, the minimal DBH of measured trees, and the region in which the biomass increases were measured. This quantity may be reported separately for the different forest strata where relevant.	2.4
2. Summary table of $\frac{44}{12}\Delta C_{ANR}(t)$, the GHG benefits from assisted natural regeneration activities, $\Delta C_{ANR,BSL}(t)$, the baseline GHG changes on the land on which assisted natural regeneration activities are proposed.	2.4
3. Summary of the difference $\left(\frac{44}{12}\cdot\Delta C_{ANR}(t)-\Delta C_{ANR,BSL}(t)\right)$, the net GHG benefits from ANR without taking emission sources into account for every year t of the crediting period in column [6] of Table 20.	4.3
4. List of the assumptions, data sources, and other information relevant to the calculation of the emissions for every source related to assisted natural regeneration.	2.5
5. Summary table of $E_{biomassLoss,ANR}(t)$, $E_{fire,ANR}(t)$, $E_{fertilization,ANR}(t)$ for every year t of the crediting period.	2.5
6. Summary of $E_{sources,ANR}(t)$, the sum of the GHG emissions sources related to assisted natural regeneration for every year t of the crediting period in the appropriate column of Table 19.	2.5

II.3 *Ex-ante* Estimation of GHG Emissions and Changes in Sinks under the Project Scenario outside the Project Area (Leakage)

II.3.1 Leakage Definitions and Inclusion in this Methodology.

Leakage has been cited as being a major obstacle for the development of avoided deforestation projects (e.g., Schlamadinger et al., 2005; Miles and Kapos, 2008). However, the mere potential for leakage does not necessarily negate the environmental integrity of an avoided deforestation project. Only in cases where potential leakage cannot be identified and quantified does leakage pose an insurmountable barrier. Project activities must incorporate measures to minimize leakage (see section II.2.1). The leakage emissions that cannot be avoided must be subtracted from the emission reductions. Under this methodology, leakage is estimated *ex-ante*, but actual NERs are based on actual leakage calculated with project monitoring data.

II.3.1.1 Categorization of Leakage and Inclusion in This Methodology

Leakage is the increase in GHG emissions outside of the project area directly attributable to the REDD project activities implemented inside of the project area. Depending on whether the increases in GHG emissions are directly attributable to the original deforestation agents, a distinction is made between primary leakage (directly attributable to the deforestation agents) and secondary leakage (not directly attributable to the deforestation agents) (Aukland et al., 2003).

Primary leakage occurs when the planned REDD project activities cause deforestation agents to engage in activities that increase GHG emissions outside of the project area. Primary leakage can be divided into the following sub-types:

> **Activity shifting**. Deforestation is not avoided, but merely displaced in whole or in part to an area outside of the project area. All activities that lead to deforestation under the baseline scenario and that are prevented under the project scenario will potentially lead to activity shifting leakage. Example 1: the protection of forest land from grazing inside the project area leads to the conversion of forest land into grazing land outside the project area. Example 2: closing down a forest for the collection of fuel-wood can increase fuel-wood collection in the immediate vicinity of the project area. Example 3: if under the baseline scenario, logging was occurring within the project area, project actions will lead to a displacement of the logging outside of the project area.
>
> **Outsourcing**. This occurs when REDD project activities lead to the purchase or contracting out of the services or commodities that were previously produced inside of the project area by the deforestation agents. For example, a logging company that was previously extracting timber within the project area, purchases timber from other operators to maintain an ongoing supply of timber to operate its sawmill. This differs from market effects (see below), since outsourcing is undertaken by the original deforestation agents and not by third parties.

Secondary leakage occurs when REDD project activities create incentives for people other than the original deforestation agents to increase GHG emissions elsewhere. Secondary leakage can be sub-divided into the following sub-types:

> **Market effects.** This occurs when REDD project activities lead to shifts in supply or demand of the products and services affected by the project actions, which will increase GHG emissions. For example, the protection of previously logged forest land might decrease the local supply of timber, thereby causing a rise in timber prices and an increase in logging activities by third parties. Market effect leakage typically occurs in areas which were previously under commercial timber harvesting or commercial production of other forest-related commodities. It is less likely to occur in projects where deforestation is primarily driven by subsistence activities since these activities do not affect markets for the products involved.
>
> **Super-acceptance of alternative livelihood options** occurs when the REDD project activities or livelihood options are not only adopted by the original deforestation agents, but also by other local actors. This may even cause an influx of people attracted into the general project area from regions outside of the original project boundaries. This may result in either positive or negative leakage:
>
> > **Positive**. If people other than the original deforestation agents switch from high-GHG-emitting activities to low-GHG-emitting livelihood options promoted by the project, there may be an overall reduction in GHG emissions.

Negative. People other than the original deforestation agents can adopt some of the REDD project activities that increase GHG emissions, such as using fertilizer to increase agricultural yields.

If the applicability criteria of this methodology are met, **activity shifting** is the main source of leakage. **Outsourcing** and **market-effect leakage** will be negligible because this methodology does not allow that timber from the project area is sold or transferred beyond the project participants. Any credits that are attributed to stopping illegal timber harvesting for commercial on-sale are discounted for market leakage using the factors on p 26 in VCS 2007.1, 2008. GHG benefits from **positive super-acceptance** are not accounted for. Project proponents must track adoption rates and potential negative effects due to super-acceptance of alternative livelihoods in their monitoring plan.

The procedure to quantify leakage differs between drivers that are geographically constrained and geographically unconstrained drivers (see Table 14).

Table 14. Distinction between geographically constrained and geographically unconstrained drivers.

Geographically constrained driver categories	Geographically unconstrained driver categories
• Fuel-wood collection or charcoal production • Conversion of forest land to crop-land by local communities • Conversion of forest land to settlements • Logging of timber for local and domestic use • Forest fires induced by local communities	• Forest fires induced by migrants, hunters, or other non-local or migratory people • Illegal logging of timber for commercial on-sale • Conversion of forest land to crop-land by migrants

- *Ex-ante* activity-shifting leakage from the **geographically constrained drivers** uses a factor-approach based on rural appraisals and expert knowledge; *ex-post* leakage from these drivers is based on the remotely sensed deforestation/degradation rates in the leakage area.
- *Ex-ante* activity-shifting leakage from the **geographically unconstrained drivers** is based on a factor-approach based on rural appraisals and expert knowledge. *Ex-post* activity shifting leakage is based on a factor-approach using conservative assumptions. Market leakage is based on coefficients set by the VCS AFOLU guidance.

II.3.2 Step 10 – Estimate Leakage from Geographically Constrained Drivers

Leakage from geographically constrained drivers is estimated *ex-ante* by calculating deforestation and forest degradation rates in the area adjacent to the project area subject to leakage, i.e. the leakage belts.

(1) First, calculate the leakage-induced increase in deforestation/degradation due to project activities.

(2) Subsequently, demarcate the location and the size of the leakage belts using a GIS analysis.

(3) Next, estimate forest strata- specific deforestation and forest degradation rates in the leakage belts. Calculate first the total deforestation and degradation rates in the leakage belts by adding the leakage-induced increases in deforestation/degradation to the baseline deforestation/ degradation rates in the leakage belts. Estimate then forest strata- specific deforestation and forest degradation rates using the land use model previously calibrated (section II.1.5) for every year of the crediting period.

II.3.2.1 Step 10A – Calculate the Leakage-Induced Increase in Deforestation and Forest Degradation Rates

$$\Delta D_{LK,DF}(t) = RelativeLeakageImpact_{DF}(t) \cdot D_{projectArea,baselineScenario,DF}(t) \tag{79}$$

$$\Delta D_{LK,DG}(t) = RelativeLeakageImpact_{DG}(t) \cdot D_{projectArea,baselineScenario,DG}(t) \tag{80}$$

where:

$\Delta D_{LK,DF}(t)$ and $\Delta D_{LK,DG}(t)$	=	Leakage-Induced Increase in deforestation and forest degradation rates for year t of the crediting period. [ha yr^{-1}]
$RelativeLeakageImpact_{DF}(t)$ and $RelativeLeakageImpact_{DG}(t)$	=	Total relative impact of leakage on the decrease in GHG emissions due to project activities for deforestation and forest degradation respectively for year t of the crediting period. [-]
$D_{projectArea,baselineScenario,DF}(t)$, and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area for year t of the crediting period. [ha yr^{-1}]

The relative impact of leakage is quantified by *ex-ante* leakage cancellation factors, which express the driver-specific relative amount of leakage for the amount of deforestation or degradation that is avoided. This quantity describes the proportion of the (expected) gross emission reductions inside the project area that are lost again due to leakage outside of the project area. Only changes that are directly attributed to project activities should be included in the cancellation rate. For example, if preventing illegal encroachment within the project area by patrolling saves 500 ha of forest per year, but directly leads to an increased deforestation outside of the project area of 300 ha, the cancellation rate of illegal encroachment prevention is 60%. Once the leakage cancellation rates $leakage(d)$ are fixed for every driver d, the $RelativeLeakageImpact$ can be calculated as following:

$$RelativeLeakageImpact_{DF}(t) = \sum_{d=1}^{nrCDrivers} leakage(d) \cdot RelativeDriverImpact_{DF}(t,d) \tag{81}$$

$$RelativeLeakageImpact_{DG}(t) = \sum_{d=1}^{nrCDrivers} leakage(d) \cdot RelativeDriverImpact_{DG}(t,d) \quad (82)$$

where:

$RelativeLeakageImpact_{DF}(t)$ and $RelativeLeakageImpact_{DG}(t)$	=	Total relative impact of leakage on the decrease in GHG emissions due to project activities for deforestation and forest degradation respectively. [-]
$nrCDrivers$	=	Number of geographically constrained drivers. [-]
$leakage(d)$	=	Leakage cancellation rate for avoiding deforestation/degradation of fuel-wood collection. [-]
$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DG}(t,d)$	=	Relative impact of a driver d on deforestation and forest degradation, respectively for year t of the crediting period. [-]

Every driver is assigned a leakage cancellation rate based expert knowledge, participatory appraisals and past project experience.

- **Fuel-wood collection or charcoal production**. Estimate the leakage cancellation rate as:

$$leakage(fuel\text{-}wood) = \frac{FW_{project} - FW_{allowed}}{FW_{baseline} - FW_{allowed}} \quad (83)$$

where:

$leakage(fuel\text{-}wood)$	=	Leakage cancellation rate for avoiding deforestation/degradation of fuel-wood collection. [-]
$FW_{baseline}$	=	Biomass (dry matter) of fuel-wood collected by project participants under the baseline scenario. [m^3 yr^{-1}]
$FW_{project}$	=	Biomass (dry matter) of fuel-wood collected by project participants under the project scenario. [m^3 yr^{-1}]
$FW_{allowed}$	=	Biomass (dry matter) of allowed fuel-wood collection in the project area under the project scenario. This amount is typically fixed in a management plan. [m^3 yr^{-1}]

A number of project activities may be implemented to decrease the need for the resource either directly (e.g., the introduction of fuel-efficient woodstoves) or indirectly by providing alternative sources for the resource (e.g., propane stoves instead of woodstoves) must be used. Estimate $B_{projectScenario}$ as:

$$FW_{project} = \sum_{i=1}^{nrfuelWoodReductionActions} adoption(i) \cdot \left(1 - efficiency(i)\right) \cdot FW_{baseline} \qquad (84)$$

where:

$nrfuelWoodReductionActions$	=	The number of project activities that reduce the need for fuel-wood. E.g., introduction of fuel-efficient wood-stoves, mosquito nets for livestock, biogas plants. [-]
$adoption(i)$	=	Adoption rate of project activity i which reduces fuel-wood consumption. [-]
$efficiency(i)$	=	Rate at which project activity i reduces fuel-wood consumption. [-]
$FW_{baseline}$	=	Biomass (dry matter) of fuel-wood collected in the project area in the baseline scenario. [Mg DM yr^{-1}]

- **Conversion of forest land to settlements by local communities**

$$leakage(settlement\ conversion) = \frac{\Delta area_{settlement,project} - \Delta area_{settlement,allowed}}{\Delta area_{settlement,baseline} - \Delta area_{settlement,allowed}} \qquad (85)$$

where:

$leakage(settlement\ conversion)$	=	Leakage cancellation rate for avoiding deforestation/degradation due to conversion of forest land to settlements. [-]
$\Delta area_{settlement,baseline}$	=	Area that would be converted to settlements by participating communities under the baseline scenario. [ha yr^{-1}]
$\Delta area_{settlement,project}$	=	Area that will be converted to settlements by participating communities under the project scenario. [ha yr^{-1}]
$\Delta area_{settlement,allowed}$	=	Area that will be converted to settlements after within the project area under the project scenario. This amount is fixed in a management plan. [ha yr^{-1}]

If the data are missing to calculate $leakage(settlement\ conversion)$, use a conservative rate of 0.9. This is allowed because no *ex-post* NERs are dependent on this rate estimated.

- Conversion of forest land to crop-land by participating communities

$$leakage(cropland\ conversion\ by\ participating\ communities) = \frac{\Delta area_{cropLand,project} - \Delta area_{cropLand,allowed}}{\Delta area_{cropLand,baseline} - \Delta area_{cropLand,allowed}} \quad (86)$$

where:

$leakage(cropland\ conversion)$	=	Leakage cancellation rate for avoiding deforestation/degradation due to conversion of forest land to settlements. [-]
$\Delta area_{cropLand,baseline}$	=	Area that would be converted to cropland by participating communities under the baseline scenario. [ha yr^{-1}]
$\Delta area_{cropLand,project}$	=	Area that will be converted to cropland by participating communities under the project scenario. [ha yr^{-1}]
$\Delta area_{cropLand,allowed}$	=	Area that will be converted to cropland after within the project area under the project scenario. This amount is fixed in a management plan. [ha yr^{-1}]

If the data are missing to calculate $leakage(cropland\ conversion)$, use a conservative rate of 0.9. This is allowed because no *ex-post* NERs are dependent on this rate estimated.

- **Logging of timber for local and domestic use.** The timber needed for local and domestic use is non-elastic. Therefore, assume a leakage cancellation rate of 100 %

$$leakage(domestic\ timber) = 100\% \quad (87)$$

- **Forest fires induced by local communities.** Most forest fires that are avoided through fire prevention activities and education will not lead to increased occurrence of forest fires outside of the project area. Still, assume a conservative leakage cancellation rate of 25% as fires induced by hunters or beekeepers may be displaced by patrolling the project areas.

$$leakage(forest\ fires\ by\ participating\ communities) = 25\% \quad (88)$$

Combine all cancellation rates for avoided deforestation or avoided forest degradation in two separate tables such as Table 15.

Table 15. Example of a summary of deforestation rates in reference region, project area, and the leakage area according to the driver of deforestation, as identified in section II.1.3.1.

	Project Area				Leakage Area	
	Baseline Scenario		Project Scenario		Project Scenario	
Driver	Relative Contribution (%)	Deforested Area (ha)	Relative Change (%)	Deforested Area (ha)	Cancellation Rate (%)	Deforested Area (ha)
Agricultural expansion	50	651	25	163	10	49
Settlement expansion	10	130	50	65	50	33
Fire wood collection	10	130	25	33	75	73
Timber harvesting	20	260	10	26	100	234
Illegal logging	10	130	10	13	90	105
TOTAL	100	1302		299	49	494

II.3.2.2 Step 10B – Demarcate the Leakage Belts

Leakage from drivers that are geographically constrained will remain close to the project areas. Leakage from these drivers is monitored in an *ex-ante* fixed geographical region around each discrete project area parcel (a leakage belt). The leakage belts are identical for all geographically constrained drivers (see section II.3.2 and Table 14). A correct *ex-ante* demarcation of each leakage belt is crucial to accurately account for the GHG benefits of the REDD project since the leakage belt is the area where leakage from geographically constrained drivers will be monitored and deducted from the actual NERs. The size and location of the leakage belts is determined using a cost-of-transportation-based GIS approach and participatory rural appraisals. Use the following steps:

1) Determine the average "cost" to move across an LULC class, forest stratum, or road/track. The relative costs must be calculated by reciprocating the maximal speed for every class or road category and relevant mode of transportation, and therefore represent the fastest time it takes to cross a set distance. The speeds were analyzed in section II.1.3.3.
2) Using a GIS, generate a raster map of the reference region in which every pixel contains the cost to cross this pixel, based on the class or roads/tracks on this pixel. The cost to cross areas that are not accessible to deforestation agents must be set to an arbitrary large value. Examples of inaccessible areas include protected areas, national parks, economic land concessions, and large plantations.
3) This map must have an identical resolution as the remote sensing images of the historical reference period.

4) Using the cost map, generate a cost-distance map of the reference region in which every pixel contains the cost (time) to reach the nearest point of the project area.
5) For every agent of deforestation/degradation, estimate the extra time this agent is willing to take to move their deforestation activities from the project area to the nearest accessible forest.
6) Select the area in the cost-distance map that is accessible from the boundary of the project area within the maximal time determined in the previous step. Therefore, when different agents and drivers of deforestation are active, the **most mobile deforestation agent** shall determine the size of a leakage belt. Note that the leakage area should be fully encompassed within the reference region. Increase the size of the reference region, if necessary, to accommodate the defined leakage belts.

II.3.2.3 Step 10C – Calculate the Forest Strata-specific Deforestation and Degradation Rates in the Leakage Belts

- Once the leakage area is demarcated, the total deforestation/ degradation rates in the leakage belts are calculated using:

$$D_{leakageArea,baselineScenario,DF}(t) = D_{projectArea,baselineScenario,DF}(t)\frac{size_{leakageArea}}{size_{projectArea}} \quad (89)$$

$$D_{leakageArea,baselineScenario,DG}(t) = D_{projectArea,baselineScenario,DG}(t)\frac{size_{leakageArea}}{size_{projectArea}} \quad (90)$$

$$D_{leakageArea,projectScenario,DF}(t) = \Delta D_{LK,DF}(t) + D_{leakageArea,baselineScenario,DF}(t) \quad (91)$$

$$D_{leakageArea,projectScenario,DG}(t) = \Delta D_{LK,DG}(t) + D_{leakageArea,baselineScenario,DG}(t) \quad (92)$$

where:

$D_{leakageArea,baselineScenario,DF}(t)$ and $D_{leakageArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the leakage area for year t of the crediting period. [ha yr^{-1}]
$D_{projectArea,baselineScenario,DF}(t)$ and $D_{projectArea,baselineScenario,DG}(t)$	=	Baseline rate of deforestation/degradation within the project area for year t of the crediting period. [ha yr^{-1}]
$size_{leakageArea}$	=	Size of the leakage area. [ha]
$size_{projectArea}$	=	Size of the project area. [ha]
$D_{leakageArea,projectScenario,DF}(t)$ and $D_{leakageArea,projectScenario,DG}(t)$	=	Rate of deforestation/degradation within the leakage area under the project scenario for year t of the crediting period. [ha yr^{-1}]
$\Delta D_{LK,DF}(t)$ and $\Delta D_{LK,DG}(t)$	=	Leakage-Induced increase in deforestation and forest degradation rates for year t of the crediting period. [ha yr^{-1}]

- The total deforestation and forest degradation rates in the leakage area are calculated by adding the leakage-induced increase in deforestation/degradation rates to the baseline deforestation/ degradation rates. The baseline deforestation and forest degradation rates are calculated by taking the size-wise proportion of the deforestation/degradation rates in the project area under the baseline scenario. Add the total deforestation and forest degradation rates in the leakage area in two separate tables such as Table 15.
- Subsequently, estimate the forest strata- specific deforestation and forest degradation rates for every year of the crediting period using the land use model previously calibrated (section II.1.5).

II.3.3 Step 11 – Estimate Leakage from Geographically Unconstrained Drivers and Market Leakage

Activity-shifting leakage from geographically unconstrained drivers and market leakage is quantified using a factor approach in both the *ex-ante* and *ex-post* cases. Default leakage cancellation factors must be used.

- The potential for leakage from illegal logging of timber for commercial on-sale is very high. Use the maximal market-leakage factor of 70% set by the VCS AFOLU guidance (VCS 2007.1, 2008).

$$leakage(illegal\ timber) = 70\% \quad (93)$$

- Forest fires set by people outside of the participating communities. This leakage rate will be very high, set conservatively to 70%.

$$leakage(forest\ fires\ by\ others) = 70\% \quad (94)$$

- Conversion of forest land to crop-land by migrants or other people outside of the participating communities. This leakage rate will be very high, set conservatively to 70%.

$$leakage(cropland\ conversion\ by\ others) = 70\% \quad (95)$$

In contrast to the deforestation by geographically constrained agents, it is not possible to predict in which forests the deforestation through leakage will take place. To remain conservative, assume that this happens in the forest with the highest average biomass stock density. Therefore use the largest emission factor EF_{max} for calculating the emissions. The total emissions from leakage from activity shifting by geographically constrained drivers and market leakage, $E_{otherLeakageSources}(t)$, is calculated by adding the impact of deforestation

$$GHG_{otherLeakageSources}(t) = + \frac{44}{12} \cdot EF_{max} \cdot D_{projectArea,baselinScenario,DF} \cdot \sum_{d=1}^{nrUDrivers} leakage(d) \cdot RelativeDriverImpact_{DF}(t,d) + \frac{44}{12} \cdot EF_{max} \cdot D_{projectArea,baselinScenario,DG} \cdot \sum_{d=1}^{nrUDrivers} leakage(d) \cdot RelativeDriverImpact_{DG}(t,d) \quad (96)$$

where:

$GHG_{otherLeakageSources}(t)$	=	GHG emissions from leakage due to unconstrained geographic drivers and market leakage for year t of the crediting period. [MTCO2e]
EF_{max}	=	The most negative emission factor from Table 13. [MTCO2e]
$D_{projectArea,baselinScenario,DF}$ and $D_{projectArea,baselinScenario,DG}$	=	Baseline rate of deforestation and forest degradation respectively within the project area for year t of the crediting period. [ha yr^{-1}]
$nrUDrivers$	=	Number of drivers that are geographically unconstrained. [-]
$leakage(d)$	=	Leakage cancellation rate for avoiding deforestation/degradation of driver d. [-]
$RelativeDriverImpact_{DF}(t,d)$ and $RelativeDriverImpact_{DF}(t,d)$	=	Relative impact of a driver d on deforestation and forest degradation, respectively for year t of the crediting period. [-]

Calculate values for $E_{otherLeakageSources}(t)$ for every year of the project crediting period and report in column [5] of Table 20.

II.3.4 Step 12 – Estimate Emission sources from Leakage Prevention Activities

Increases in any of the non-carbon pool-related GHG emissions outside of the project area but directly attributable to the project activities ($E_{sources,leakagePrevention}$) must be accounted for. Use the methodologies explained before (section II.2.3.1) to calculate this increase in GHG emissions.

$$E_{sources,leakagePrevention}(t) = \Delta E_{rice}(t) + \Delta E_{fertilization}(t) + \Delta E_{livestock}(t) \quad (97)$$

where:

$E_{sources,leakagePrevention}(t)$	=	Emission sources from leakage prevention activities for year t of the crediting period. [MTCO2e]
$\Delta E_{rice}(t)$	=	Annual difference in GHG emissions due to increased use of flooded rice production systems as agricultural intensification measures for year t of the crediting period. [MTCO2e]

$\Delta E_{fertilization}(t)$	=	Annual difference in GHG emissions due to increased use of N fertilizer as an agricultural intensification measure for year t of the crediting period. [MTCO2e]
$\Delta E_{livestock}(t)$	=	Annual difference in GHG emissions by enteric fermentation and manure management from increased animal stocking rates as an agricultural intensification measure for year t of the crediting period. [MTCO2e]

The significance of these and other emissions is tested according to the methodology provided in EB31 appendix 16 to determine whether it must be included (see section II.4.1). If an emission source is found insignificant, it may be omitted.

II.3.4.1 Step 12A – Estimate GHG Emissions from Increased Rice Production (ΔE_{rice})

Increasing rice production by flood irrigation is allowed as an agricultural intensification measure within the boundary of the leakage area. Anaerobic decomposition of organic material in flooded rice fields produces methane, which escapes to the atmosphere primarily by transport through the rice plants. The annual amount of CH_4 emitted from a given area of rice is a function of specific conditions under which the rice is grown (number and duration of crops grown, water regimes before and during cultivation period, and organic and inorganic soil amendments). This methodology adopts the method from 2006 GPG AFOLU guidelines (section 5.5; equations 5.1 and 5.2). Methane emissions from rice cultivation can be calculated as.

$$\Delta E_{rice}(t) = GWP_{CH4} \cdot \sum_{i=1}^{nrRiceCultivationClasses} \left(EF_c(i) \cdot SF_w(i) \cdot SF_p(i) \cdot SF_o(i) \cdot SF_{s,r}(i) \cdot \Delta t_{rice}(i) \cdot \Delta area_{rice}(t,i) \right) \tag{98}$$

$\Delta E_{rice}(t)$	=	Annual difference in GHG emissions due to increased use of irrigation or rice production systems as agricultural intensification measures. [MTCO2e yr^{-1}]
GWP_{CH4}	=	Global warming potential for CH_4 (23 for the first commitment period). [-]
$nrRiceCultivationClasses$	=	Rice cultivation conditions class (combination of ecosystem, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary). [-]
$EF_c(i)$	=	Baseline emission factor for continuously flooded fields without organic amendments. The IPCC default for $EF_c(i)$ is 1.30 kg CH_4 ha^{-1} day^{-1} (with error range of 0.80–2.20, Table 5.11), estimated by a statistical analysis of available field measurement data. [kg CH_4 ha^{-1} day^{-1}]
$SF_w(i)$	=	Scaling factor to account for the differences in water regime during the cultivation period for conditions i (from Table 5.12). [-]
$SF_p(i)$	=	Scaling factor to account for the differences in water

		regime in the pre-season before the cultivation period for conditions i (from GPG-LULUCF Table 5.13). [-]
$SF_o(i)$	=	Scaling factor for type and amount of organic amendment applied for conditions i (from GPG-LULUCF Equation5.3 and Table 5.14). [-]
$SF_{s,r}(i)$	=	Scaling factor should vary for both type and amount of organic amendment applied for conditions i (from GPG-LULUCF Equation 5.3 and Table 5.14). [-]
$\Delta t_{rice}(i)$	=	Cultivation period of rice for conditions i during a cultivation year. [days yr^{-1}]
$\Delta area_{rice}(t,i)$	=	Difference in harvested area of rice for conditions i between project scenario and baseline scenario for year t. [ha yr^{-1}]

The classification of the annual harvest area of rice into specific conditions i needs to be done for at least three baseline regimes, namely irrigated, rain fed, and upland rice systems. It is encouraged to incorporate as many of the conditions that influence CH_4 emissions as possible into the classification. Further guidance can be found in the 2006 GPG AFOLU guidelines, section 5.5.

Add annual values of $\Delta E_{rice}(t)$ to the summary table of all GHG emissions due to project activities (Table 19).

II.3.4.2 Step 12B – Estimate GHG Emissions from Increased Fertilization, $\Delta E_{fertilization}$

To estimate emissions of nitrous oxide (N_2O) from nitrogen fertilization, it is necessary to have good data on the amount of fertilizer applied in the LULC classes established on deforested lands. The amount of fertilizer applied can vary depending on soil fertility, economic capacity of the land user and stage of the production cycle. These factors must be analyzed and duly accounted for in the estimation of the amount of fertilizer applied in each LULC class.

The amount of fertilizer applied should be estimated as an average per hectare over the production cycle of each LULC class. N_2O emissions from fertilization are estimated following Equation 3.2.18 in the 2003 IPCC GPG-LULUCF:

$$\Delta E_{fertilization}(t) = \frac{44}{28} \cdot GWP_{N2O} \cdot EF_{N\text{-}inputs} \cdot \sum_{i=1}^{nrfertilizerClasses} \Delta area_{fertilized}(t,i)\left(N_{synthetic}(i) \cdot (1 - f_{GASF}) + N_{organic}(i) \cdot (1 - f_{GASM})\right) \quad (99)$$

$\Delta E_{fertilization}(t)$	=	Annual difference in GHG emissions due to increased use of N fertilizer as an agricultural intensification measure for year t of the crediting period. [MTCO2e yr^{-1}]
GWP_{N2O}	=	Global Warming Potential for N_2O (IPCC default = 310 for the first commitment period). [-]

$EF_{N\text{-}inputs}$	=	Emission factor for emissions from N input. Use the default emission factor of 1.25 % of applied N as noted in IPCC GPG 2000.
$nrfertilizerClasses$	=	Number of cropping systems in which fertilizer is used. [-]
$\Delta area_{fertilized}(t,i)$	=	Difference in area of cropping system i between project scenario and baseline scenario during year t of the crediting period. [ha]
$N_{synthetic}(i)$	=	Average per hectare annual amount of synthetic fertilizer nitrogen applied within the LULC class i. [Mg N ha^{-1} yr^{-1}]
f_{GASF}	=	Fraction that volatilizes as NH_3 and NO_x for synthetic fertilizers. Use the default value of 0.1 from the 1996 IPCC Guideline. [-]
$N_{organic}(i)$	=	Average per hectare annual amount of organic fertilizer nitrogen applied within the LULC class i. [Mg N ha^{-1} yr^{-1}]
f_{GASM}	=	Fraction that volatilizes as NH_3 and NO_x for organic fertilizers. Use the default value of 0.2 in the 1996 IPCC Guideline. [-]

Add annual values of $\Delta E_{fertilization}$ to the summary table of all GHG emissions due to project activities (Table 19).

II.3.4.3 Step 12C – Estimate GHG Emissions from Increased Livestock Stocking Rates, $\Delta E_{livestock}$

This section is based on the approved CDM methodology AR-AM0006 version 2. As specified as an applicability condition, all forage produced by the project shall have a similar nutritional value and digestibility, and will support only a single livestock group with a single manure management system. If these conditions are not met, this methodology cannot be used.

For ex ante estimates of leakage emissions, a suitable livestock group and manure management system may be specified according to knowledge of intended project activities, forage types, and local farming practices15. Alternatively, the forage-fed livestock group may be selected ex ante as the pre-project livestock group that is fed the largest amount of forage most similar to that to be produced by the project, as determined from data obtained by a survey on livestock forage feeding from households likely to be involved in the project—at least 30 households or 10% of households, whichever is greater, should be sampled. The manure management system to be used in ex ante emissions estimation shall be selected as the most common manure management system for the identified forage-fed livestock group. Characteristics of the forage-fed livestock group that will help select appropriate enteric CH_4 emission factors should also be identified and determined - by household survey if necessary - including, for example, mean weight, growth rate, and milk production.

The following types of GHG emissions from forage-fed livestock are accounted for:

$$\Delta E_{livestock}(t) = \Delta E_{enteric,CH4}(t) + \Delta E_{manure,CH4}(t) + \Delta E_{manure,N2O}(t) \quad (100$$

where:

$\Delta E_{livestock}(t)$	=	Increased GHG emissions from forage-fed livestock for year t of the crediting period. [MTCO2e]
$\Delta E_{enteric,CH4}(t)$	=	Increases in CH_4 emissions from enteric fermentation due to increases in stocking rates for year t of the crediting period. [MTCO2e]
$\Delta E_{manure,CH4}(t)$	=	Increases in CH_4 emissions from manure management due to increases in livestock stocking rates for year t of the crediting period. [MTCO2e]
$\Delta E_{manure,N2O}(t)$	=	Increases in N_2O emissions from manure management due to increases in stocking rates for year t of the crediting period. [MTCO2e]

A detailed description on how each of these three terms must be calculated follows. Add annual values of $\Delta E_{livestock}(t)$ to the summary table of all GHG emissions due to project activities (Table 19).

- Methane emissions from **enteric fermentation,** $\Delta E_{enteric,CH4}(t)$, can be calculated using the following formula

$$\Delta E_{enteric,CH4}(t) = EF \cdot \Delta P(t) \cdot \frac{GWP_{CH4}}{1000} \qquad (101)$$

where:

$\Delta E_{enteric,CH4}(t)$	=	Annual difference in GHG emissions by enteric fermentation from increased animal stocking rates as an agricultural intensification measure. [MTCO2e yr^{-1}]
EF_1	=	Enteric CH_4 emission factor for the main livestock group. Use default values from Tables 10.10 and 10.11 in the 2006 IPCC Guidelines for AFOLU. [kg CH_4 $head^{-1}$ yr^{-1}]
$\Delta P(t)$	=	Difference in equivalent number of forage-fed livestock in LULC between project scenario and baseline scenario [heads]. If no direct head count is available, this quantity may be estimated by dividing the total forage production used for feed [kg DM ha^{-1} yr^{-1}] by the annual biomass intake per head [kg DM $head^{-1}$ day^{-1}]. [-]
GWP_{CH4}	=	Global warming potential for CH_4 (with a value of 23 for the first commitment period). [-]

The production of forage can be estimated by collecting production rates from the literature that represents the shrub species, climate, soil conditions and other features of the areas in which forage will be produced. Sampling surveys are a good option.

For data on daily biomass intake use local data or data that are applicable to the local conditions according to peer-reviewed literature or the national GHG inventory. When selecting a value for daily biomass intake, ensure that the chosen data are applicable to both the forage types to be produced and the livestock group.

Table 16. Approximate values of daily biomass intake (DM = dry matter) for different type of animals (adapted from AR-AM0003; feed intake data from Crutzen *et al.* (1986).

Animal Type	Region	Daily Feed Intake [MJ head^{-1} day^{-1}]	Daily Biomass Intake [kg DM head^{-1} day^{-1}]
Sheep	Developed Countries	20	2.0
	Developing Countries	13	1.3
Goats	Developed Countries	14	1.4
	Developing Countries	14	1.4
Mules/Asses	Developed Countries	60	6.0
	Developing Countries	60	6.0

- **Methane emissions from manure management** due to increased stocking rates, $\Delta E_{manure,CH4}(t)$

  The storage and treatment of manure under anaerobic conditions will produce CH_4. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid-based systems. The main factors affecting CH_4 emissions are the amount of manure produced and the portion of the manure that decomposes anaerobically. The former depends on the rate of waste production per animal and the number of animals, and the latter on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically and can produce a significant quantity of CH_4. The temperature and the retention time of storage greatly affect the amount of methane produced. When manure is handled as a solid (e.g. in stacks or piles), or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions and less CH_4 is produced. CH_4 emissions from manure management for the forage-fed livestock can be estimated using IPCC methods:

$$\Delta E_{manure,CH4}(t) = EF_2 \cdot \Delta P(t) \cdot \frac{GWP_{CH4}}{1000} \quad (102)$$

where:

$\Delta E_{manure,CH4}(t)$ = Difference in annual CH_4 emissions from manure management. [MTCO2e yr^{-1}]

EF_2 = Manure management CH_4 emission factor for the livestock group. Use default emission factors presented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project area. [kg CH_4 $head^{-1}$ yr^{-1}]

$\Delta P(t)$ = Increase in equivalent number of forage-fed livestock. See the previous section for a procedure to calculate this. [heads]

GWP_{CH4} = Global warming potential for CH_4 (with a value of 23 for the first commitment period). [-]

- **Increased nitrous oxide emissions from manure management** due to increased stocking rates, $\Delta E_{manure,N2O}(t)$

  Nitrous oxide emissions from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss from the system. As specified by an applicability condition, forage produced by the project must support only one livestock group and the group must have a single manure management system. The N_2O emissions from manure management for the forage-fed livestock supported by the project can be estimated using methods provided in the IPCC 2006 Guidelines for AFOLU, or in IPCC GPG 2000:

$$\Delta E_{manure,N2O}(t) = \Delta E_{manure,N2O,direct}(t) + \Delta E_{manure,N2O,indirect}(t) \quad (103)$$

$$\Delta E_{manure,N2O,direct}(t) = \frac{44}{28} \cdot \Delta P(t) \cdot N_{excr} \cdot \frac{EF_3}{1000} \cdot GWP_{N2O} \quad (104)$$

$$\Delta E_{manure,N2O,indirect}(t) = \frac{44}{28} \cdot \Delta P(t) \cdot N_{excr} \cdot f_{gas} \cdot \frac{EF_4}{1000} \cdot GWP_{N2O} \quad (105)$$

where:

$\Delta E_{manure,N2O}(t)$	=	Difference in annual GHG emissions from manure management due to increased animal stocking rates as an agricultural intensification measure. [MTCO2e yr^{-1}]
$\Delta E_{manure,N2O,direct}(t)$	=	Difference in annual GHG emissions from direct N_2O emissions from manure management. [MTCO2e yr^{-1}]
$\Delta E_{manure,N2O,indirect}(t)$	=	Difference in annual GHG emissions from indirect N_2O emissions from manure management. [MTCO2e yr^{-1}]
$\Delta P(t)$	=	Difference in equivalent number of forage-fed livestock between project scenario and baseline scenario. [heads]
N_{excr}	=	Annual average N excretion per livestock head. Annual nitrogen excretion rates must be determined for the forage-fed livestock group supported by the project. Use the default nitrogen excretion rates presented in Table 10.19 of IPCC 2006 Guidelines for AFOLU. [kg N $head^{-1}$ yr^{-1}]
EF_3	=	Emission factor for N_2O emissions from manure management for the livestock group. Use the default emission factors presented in Table 10.21 and Table 11.3 of the IPCC 2006 Guidelines for AFOLU. [-]
GWP_{N2O}	=	Global warming potential for N_2O (310 for the first commitment period). [-]
f_{gas}	=	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NOx in the manure management phase. Use the default values presented in the Table 10.22 of the IPCC 2006 Guidelines. [-]
EF_4	=	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces Use the IPCC default factor of 0.01 as noted in the IPCC 2006 Guidelines for AFOLU. [-]

PD Reporting requirements	PD section
1. Justification and assumptions made to obtain the leakage cancellation rates $leakage(d)$ for every geographically constrained deforestation driver d.	1.11
2. Summarizing table of the leakage cancellation rates $leakage(d)$ for each deforestation driver d.	1.11
3. Table with $RelativeLeakageImpact_{DF}(t)$ and $RelativeLeakageImpact_{DG}(t)$, the total relative impact of leakage on the decrease in GHG emissions due to project activities for deforestation and forest degradation respectively, together with $\Delta D_{LK,DF}(t)$ and $\Delta D_{LK,DG}(t)$, for every year t of the crediting period.	1.11
4. Decision criteria, data sources, field information, and maps used to demarcate the leakage belt.	1.11
5. A map of the leakage area with a clear indication which areas were excluded due to inaccessibility.	1.11
6. Table with $D_{projectArea,baselineScenario,DF}(t)$, $D_{projectArea,baselineScenario,DG}(t)$, $D_{leakageArea,projectScenario,DF}(t)$ and $D_{leakageArea,projectScenario,DG}(t)$ the absolute deforestation and forest degradation rates for the project and leakage areas under baseline and project scenarios for every year t of the crediting period.	1.11
7. Table with all land transitions for the leakage area under the baseline and project scenarios for every year of the next baseline validation period, use Table 18 in section II.4.1 as an example.	4.2 and 4.3
8. Justification and assumptions made to obtain the leakage cancellation rates $leakage(d)$ for every geographically unconstrained deforestation driver d.	
9. Table with $GHG_{otherLeakageSources}(t)$ for every year t of the crediting period.	
10. List of the assumptions, data sources, and other information relevant to the calculation of the emissions for sources $\Delta E_{rice}(t)$, $\Delta E_{fertilization}(t)$, and $\Delta E_{livestock}(t)$ from leakage prevention measures.	2.5
11. A report of $\Delta E_{rice}(t)$, $\Delta E_{fertilization}(t)$, and $\Delta E_{livestock}(t)$ in the relevant columns of Table 19 for every year t of the crediting period.	2.5

II.4 Step 13 – *Ex-ante* Estimation of NERs

II.4.1 Step 13A – Confirm Applicability Criterion 2; Insignificance of Long-Lived Wood Products Pool

The assumption that the long-lived wood product pool is insignificant is only valid if the contribution of the GHG benefits from avoided illegal logging to the total GHG benefits is smaller than 20%. Therefore, confirm that:

for every year of the crediting period t: (106)

$$\frac{\left(1 - leakage(illegal\ timber)\right) \cdot RelativeDriverImpact_{DF}(t, illegal\ timber)}{\sum_{d=1}^{nrDrivers}\left(1 - leakage(d)\right) \cdot RelativeDriverImpact_{DF}(t, d)} < 20\%$$

where:

$leakage(illegal\ timber)$	=	Leakage cancellation rate for avoiding deforestation/degradation of illegal timber harvesting for commercial on-sale. [-]
$RelativeDriverImpact_{DF}(t, illegal\ timber)$	=	Relative impact of all project activities on deforestation due to illegal timber during year t. [-]
$nrDrivers$	=	Number of deforestation drivers. [-]

Provide a table with the nominator, the denominator, and the quotient for every year of the crediting period.

II.4.2 Step 13B – Summarize the projected land use change

- Present a table with the total deforestation and degradation rates under the baseline and project scenarios for the project area and leakage area for every year of the project duration (see Table 17 for an example).
- Present tables with the LULC class and forest-strata specific land transitions for the project and leakage area under the baseline and project scenarios (see Table 18 for an example).
- Subtract the land transition changes under the baseline scenario from the changes under the project scenario in Table 18, and multiply with the difference of the appropriate emission factor and baseline net annual increment from Table 13 and apply all uncertainty discounting factors (see Equation 1). Perform these calculations separately for deforestation and forest degradation, report these values in columns [1] to [4] of Table 20.
- Calculate values for $GHG_{otherLeakageSources}(t)$ from the procedure in II.3.3 and report in column [5] of Table 20.
- Calculate the difference $\left(\frac{44}{12} \cdot \Delta C_{ANR}(t) - \Delta C_{ANR,BSL}(t)\right)$ the net GHG benefits from ANR without taking emission sources into account for every year t of the crediting period. Report this difference to column [6] of Table 20.
- In the case that credits from avoided degradation were excluded from the generated NERS due to insufficient accuracy of measuring forest strata, credits from the introduction of fuel-efficient woodstoves may still be issued. Calculate the ex-ante credits as following, and report in column [3] of Table 20.

$$WS(t) = 0.75 \cdot proportion_{DG}(fuelWood) \cdot \frac{44}{12} \cdot CF \cdot \rho_{wood} \cdot adoption(fuelEfficientStoves, t) \cdot \left(1 - efficiency(fuelEfficientStoves)\right) \cdot FW_{baseline}$$

(107)

where:

$WS(t)$	=	Annual emission reductions from introducing fuel-efficient wood-stoves. [MTCO2e]
$proportion_{DG}(fuelWood)$	=	Proportion of the gradual carbon loss that leads to forest degradation, respectively due to fuel-wood collection. Use the procedure detailed in Table 11 to estimate this number. [-]
CF	=	Carbon fraction of dry matter in dead wood. Use the default value of 0.5. [-]
ρ_{wood}	=	Basic wood density taken from Table GPG-LULUCF 3A.1.9. [Mg m^{-3}]
$adoption(fuelEfficientStoves, t)$	=	Adoption rate of project activity i which reduces fuel-wood consumption. Estimate based on a prediction of the willingness of local communities to adopt the alternative practice. [-]
$efficiency$	=	Rate at which project activity i reduces fuel-wood consumption. Estimate ex-ante based on (1) peer-reviewed literature, or (2) data from the manufacturer of the woodstoves. [-]
$FW_{baseline}$	=	Annual volume of fuelwood gathering in the baseline scenario, measured from social appraisals in the project area before start of the crediting period. At least 100 households or 5% of the households in the project area, whichever is smallest, must be sampled to calculate the annual volume of fuelwood under baseline conditions. [m^3 yr^{-1}]

Table 17. Example of a summary of deforestation and forest degradation rates in the baseline and project scenarios of the project and leakage areas

	Deforestation				Forest Degradation			
	Baseline Scenario		Project Scenario		Baseline Scenario		Project Scenario	
Year	Project Area [ha]	Leakage Area [ha]	Project Area [ha]	Leakage Area [ha]	Project Area [ha]	Leakage Area [ha]	Project Area [ha]	Leakage Area [ha]
1	1302	13020	299	13500	1302	13020	299	13500
2	1315	13150	302	13650	1315	13150	302	13650
3	1328	13280	305	13700	1328	13280	305	13700
4	1341	13411	308	13750	1341	13411	308	13750
5	1354	13541	311	13890	1354	13541	311	13890
…								
29	1667	16666	383	13910	1667	16666	383	13910
30	1680	16796	386	13930	1680	16796	386	13930
SUM	44724	447237	10286	485234	44724	447237	10286	485234

Table 18. Example of a table summarizing the projected land use change in the project area under the baseline scenario (all values are ha yr^{-1})

Land transition rates in the project area under the baseline scenario [ha yr-1]																	
	Forest Degradation				Deforestation to Plantation						Deforestation to Degraded land						
year	DGE21	DGE32	DGM21	DGM32	DFE1P1	DFE2P1	DFE3P1	DFM1P1	DFM2P1	DFM3P1	DFE1D	DFE2D	DFE3D	DFM1D	DFM2D	DFM3D	…
1		75															
2	22		38														
3		33															
4					42												
…				8		24											
n					16												

II.4.3 Step 13C – Test the Significance of GHG Emissions

In this step, the significance of emission sources is determined. All insignificant emissions can be omitted from the *ex-ante* calculation of the NERs. This methodology follows the "Tool for testing significance of GHG emissions in A/R CDM project activities" from EB31 appendix 16.

The sum of increases in emissions that may be excluded must be less than 5% of the total estimated decreases in carbon pools and increases in emissions, or less than 5% of net anthropogenic removals by sinks, whichever is lower. If it is determined that a specific GHG emission source will never reach this threshold and will never become significant, it may be omitted from the monitoring plan.

Follow this procedure for each year of the project duration:

1. Include a table with all emission sources for every year of the project duration (see Table 19). Prepare a spreadsheet and calculate the sum of the emissions for every year of the project. Include annual estimates of the GHG benefits from project activities without taking emissions into account, i.e. the sum of [1] through [7] in Equation (1) to the columns of the spreadsheet.

Table 19. Estimation of GHG emissions due to project activities (all values in MTCO2e)

	Boundary poles	Emissions from Vehicles	Fire Breaks	Biomass loss from ANR	GHG emissions loss from ANR burning	GHG emissions from ANR fertilization	Increased emissions from rice	Increased emissions from fertilizer	Increased emissions from livestock
Year	$E_{fencing}$	$E_{vehicle}$	$E_{fireBreaks}$	$E_{biomassLoss,A}$	$E_{fire,ANR}$	$E_{fertilization,ANR}$	ΔE_{rice}	$\Delta E_{fertilization}$	$\Delta E_{livestock}$
1									
2									
3									
4									
…									
n									

2. Calculate the relative contributions of the project GHG emissions by sources and emissions by leakage activities according to the following equation (IPCC 2003, Eq. 5.4.1):

$$relativeContribution(E_i) = \frac{E_i}{\sum_{i=1}^{nrEmissions} E_i} \qquad (108)$$

where:

$relativeContribution(E_i)$	=	Relative contribution of each source of GHG emissions i to the sum of GHG emissions. [-]
E_i	=	GHG emissions by sources of project and possible decreases in carbon pools and leakage emissions i. [Mg DM ha^{-1}]
$nrEmissions$	=	Total number of sources of GHG emissions considered. [-]

3. Rank the project and the leakage emissions in descending order of their relative contributions $relativeContribution(E_i)$ and order them according to their ranks (i.e. the lowest emission get the highest rank and occupy the last position in the ordered sequence of emissions).
4. Start calculating the cumulative sum of the relative contributions $relativeContribution(E_i)$ (ordered according to the step 3) beginning with the lowest rank. Mark each individual GHG emission source as it is included in the summation. Cease the summation when the cumulative sum reaches the threshold of 95%.
5. The GHG emissions by sources, possible decreases in carbon pools and leakage emissions not marked in the step 4 are considered insignificant if their sum is lower than 5% of net anthropogenic removals by sinks. Otherwise, the procedure described in the step 4 shall be continued beyond the threshold of 95% until the above condition is met.
6. Sum all the significant emission sources per year of the crediting period, and report these values in column [7] of Table 20.

II.4.4 Step 13D – Estimate *Ex-ante* NERs

Use Equation (1) to estimate the *ex-ante* NERs; only use the significant GHG sources as determined in step 2. Prepare a table with all the individual terms of Equation (1). Calculate the *ex-ante* NERs for every year of the crediting period. After NERs are calculated, use Equation (2) to calculate the VCUs.

Cumulative credits from ANR activities must account for less than 20% of the cumulative credits generated by the project. For every year of the crediting period, divide [6] by the total NERS in Table 20, and confirm that the result is less than 20%.

Table 20. Overview of the total GHG accounting and calculation of the *ex-ante* NERs for the REDD project.

Crediting Period Year	Avoided Deforestation		Avoided Degradation						
	Benefits	Leakage	Benefits	Leakage	Other Leakage Sources	ANR benefits	Emission sources	NERs	VCUs
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	15000	-4000	3000	-1200	-100	2000	2000	12700	10160
2	15000	-4000	3000	-1200	-100	2000	2000	12700	10160
3	15000	-4000	3000	-1200	-100	2000	2000	12700	10160
4	15000	-4000	3000	-1200	-100	2000	2000	12700	10160
…									
n									

The numbers in square brackets in the table heading refer to the individual terms in the equation above, column [8] = [1] + [2] + [3] + [4] + [5] + [6] – [7]. Note that values in columns [2], [4], and [5] are always negative.

PD Reporting requirements	PD section
1. GHG benefits from avoided deforestation in the project and leakage area in columns [1] and [2] of Table 20.	4.4
2. GHG benefits from avoided forest degradation in the project and leakage area in columns [3] and [4] of Table 20.	4.4
3. Annual values for $GHG_{otherLeakageSources}(t)$ in column [5] of Table 20.	
4. The difference $\left(\frac{44}{12} \cdot \Delta C_{ANR}(t) - \Delta C_{ANR,BSL}(t)\right)$, the net GHG benefits from ANR without taking emission sources into account for every year t of the crediting period in column [6] of Table 20.	
5. Table with all emissions for every year of the project duration, their relative contribution, and the cut-off value used to determine which emissions were considered insignificant, see Table 19 for an example.	4.3
6. A list of all the significant emissions from project and ANR activities in column [7] of Table 20.	
7. Overview table of the total GHG accounting (see Table 20).	4.4

II.5 Step 14 – Demonstrate the Additionality Requirements

Projects are subject to the additionality rules and tests by the VCS. The VCS refers to the additionality tools approved by the CDM Executive Board. Therefore, use the latest approved version of the "Tool for the demonstration and assessment of additionality for afforestation and reforestation activities" to demonstrate additionality.

PD Reporting requirements	PD section
1. Demonstration on how the project is additional using the additionality tools from the CDM.	2.5

II.6 Overview of Data and Parameters Required for *Ex-ante* Estimates

This includes default parameters that are default or only to be monitored one time.

The codes for the source of each variable are:

e = estimated
c = calculated
m = measured on the field
p = select by project proponents
d = default value, or value looked up in table

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(1), (2)	$NERs(t)$	c	Net Emission Reductions. *Calculate based on Equation (1).*	[MTCO2e]
(1), (73)	$nrFNFtransitions$	p	Number of forest/non-forest transitions among land classes or forest strata, meaning transitions in which either the "from" or the "to" class are non-forests. *Select based on the analysis of drivers in the reference region.*	count
(1), (73)	$u_{classification}$	c	Discounting factor for uncertainty of LULC classification. *Calculate by looking up value of $u_{classification}$ in Table 8 as explained in section II.1.2.4.3.*	proportion
(1)	$\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$	c	Hectares undergoing transition i within the project area, excluding the ANR area, under the project scenario for year t. *Calculate using the land use change model as detailed in section II.2.2.*	[ha yr^{-1}]
(1)	$\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$	c	Hectares undergoing transition i within the project area, excluding the ANR area, under the baseline scenario for year t. *Calculate using the classification and stratification procedures based on remote sensing data from the historical reference period as detailed in section II.1.5.4.*	[ha yr^{-1}]
(1), (34), (73)	$u_{inventory}(i)$	c	Discounting factor for the emission factor for the transition from LULC class or forest stratum 1 to class 2 according to the uncertainty of biomass inventory. *Calculate using Equation (34).*	proportion
(1), (73)	$EF(i)$	c	Emission factor for transition i. *Calculate using the procedure detailed in the "Emission Factor for transition", section II.2.4.3.*	[MTCO2e ha^{-1}]
(1)	$\Delta area_{leakageArea,projectScenario}(t,i)$	c	Hectares undergoing transition i within the leakage area under the project scenario for year t. *Calculate using the land use change model applied to the total rates of deforestation and forest degradation, as explained in section II.3.2.3.*	[ha yr^{-1}]
(1)	$\Delta area_{leakageArea,baselineScenario}(t,i)$	c	Hectares undergoing transition i within the leakage area under the baseline scenario during year t. *Calculate using the classification and stratification procedures based on remote sensing data from the historical reference period as detailed in section II.1.5.4.*	[ha yr^{-1}]
(1)	$u_{stratification}$	c	Discounting factor for NERs from avoided degradation, based on the accuracy of stratification, i.e. dividing forest into individual forest biomass classes. *Calculate by looking up value of $u_{classification}$ in Table 8 as explained in section II.1.2.4.3.*	proportion

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(1), (96)	$GHG_{otherLeakageSources}(t)$	c	GHG emissions from leakage due to unconstrained geographic drivers and market leakage for year t of the crediting period. *Calculate using Equation (96).*	[MTCO2e]
(1), (73), (75), (77)	$nrANRstrata$	p	Number of strata within the project area on which ANR activities are proposed. *The number of ANR strata is dependent on the ANR management plan designed by the project proponents.*	count
(1), (71)	$\Delta C(t,i)$	c	Carbon stock change for ANR stratum i for year t during the crediting period. *Calculated using Equation (72).*	[Mg C yr^{-1}]
(1), (73)	$NAI(i)$	c	Net annual increment due to natural regeneration and succession for the "from" class of transition i. *Use the following sources (in order of preference):* *(1) Values measured by the project proponents in the project area.* *(2) National or local growth curves and tables that are usually used in national or local forest inventories.* *(3) Values from peer-reviewed literature.* *(4) Values from GPG-LULUCF Table 3A.1.5. These values are representative for regeneration in well-managed forests, and will therefore be conservative.* *This is further described in section II.1.4.2.*	[Mg DM ha^{-1} yr^{-1}]
(1), (73)	$area_{projectAreaWithANR,baselineScenario}(t,i)$	m	Size of strata i within the project area on which ANR activities are proposed for year t. *Calculate based on the modeling procedure referred to in section II.1.5.4.*	[ha]
(1), (73)	$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$	m	Hectares undergoing transition i within the ANR area under the baseline scenario for year t. *Calculate based on the modeling procedure referred to in section II.1.5.4.*	[ha yr^{-1}]
(1), (66)	$E_{sources,projectArea}(t)$	c	Emission sources from project activities within the forests of the project area for year t of the crediting period. *Calculate using Equation (66).*	[MTCO2e yr^{-1}]
(1), (97)	$E_{sources,leakagePrevention}(t)$	c	Emission sources from leakage prevention activities for year t of the crediting period. *Calculate using Equation (97).*	[MTCO2e]
(1), (74)	$E_{sources,ANR}(t)$	c	Emissions of sources from methane, nitrous oxide, fuel-CO_2 and biomass removal from ANR activities during year t of the crediting period. *Calculate using Equation (74).*	[MTCO2e]
(1), (2)	$VCUs(t)$	c	Voluntary Carbon Units. *Calculate based on Equation (2).*	[MTCO2e]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(2)	$buffer$	c	Buffer withholding percentage. *Select according to the project's conditions and the tool for AFOLU non-permanence risk analysis and buffer determination from the VCS.*	[-]
(3)-(8), (11)-(20)	L_i	c	Annual carbon loss associated with driver i. *Calculate using Equations (3) to (8).*	[Mg C yr^{-1}]
(3), (107)	$FW_{baseline}$	m	Annual volume of fuelwood gathering in the baseline scenario. *Measure from (in order of preference):* 1. *Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* 2. *Recent (<10 yr) peer-reviewed scientific literature in the reference region, or* 3. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.* If emission reductions from avoided degradation were excluded due to insufficient accuracy, in which case $u_{classification} = 0$, and emission reductions from fuel-efficient woodstoves are included, $FW_{baseline}$ may only be measured using the first option, participatory rural appraisals.	[m^3 yr^{-1}]
(3), (67), (107)	ρ_{wood}	d	Basic wood density. *Use default factor from Table GPG-LULUCF 3A.1.9.*	[Mg DM m^{-3}]
(3)	BEF_2	d	Biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark). *Use default factor from GPG-LULUCF Table 3A.1.10.*	[-] dimensionless
(1), (3), (29), (67), (72), (107)	CF	d	Carbon fraction of dry matter in dead wood. *Use the default value of 0.5.*	[Mg C (Mg DM)$^{-1}$]
(4)	$area_{baseline,fire}(i)$	m	Forest area in the project area affected by disturbances from forest fires in forest stratum i. *Use the following sources (in order of preference):* 1. *Participatory rural appraisals conducted by project proponents* 2. *Recent (<10 yr) peer-reviewed scientific literature in the reference region* 3. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region* 4. *Expert opinion.*	[ha yr^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(4), (35)	E	d	Average combustion efficiency of the above-ground tree biomass (dimensionless). *Use the following sources (in order of preference):* *1. Project-specific measurements* *2. Regionally valid estimates* *3. Estimates from Table 3.A.14 of IPCC GPG LULUCF* *4. If no appropriate combustion efficiency can be used, use the IPCC default of 0.5.*	[-]
(4), (35)	P	d	Average proportion of mass burnt from the above-ground tree biomass. *Use default factors from GPG-LULUCF Table 3A.1.13.*	[-]
(4), (5), (6), (29), (33), (40), (69), (75), (77)	$\boldsymbol{C}(i)$	c	Average total carbon stock density of forest stratum $\boldsymbol{i}$. *Calculate using Equation (29).*	[MT C ha^{-1}]
(4)	$\Delta B_{forestFires}$	m	Biomass consumption for forest fires. *Use default factors from GPG-LULUCF Table 3A.1.13.*	[Mg DM ha^{-1}]
(5)	$\Delta area_{baseline,cropland}(i)$	m	Forest area converted from forest stratum i to cropland in the project area under baseline conditions at the start of the project. *Measure from (in order of preference):* *1. Remote sensing analyses in the reference region, see section II.1.2.5* *2. Participatory rural appraisals conducted by project proponents;* *3. Recent (<10 yr) peer-reviewed scientific literature in the reference region, or* 4. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.*	[ha yr^{-1}]
(6)	$\Delta area_{baseline,settlement}(i)$	m	Average forest area converted from forest stratum i to settlements in the reference region under baseline conditions. *Measure from (in order of preference):* *1. Remote sensing analyses in the reference region, see section II.1.2.5* *2. Participatory rural appraisals conducted by project proponents;* *3. Recent (<10 yr) peer-reviewed scientific literature in the reference region, or* 4. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.*	[ha yr^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(7)	$IT_{baseline}$	m	Annually extracted volume of illegally harvested timber, roundwood. *Measure from (in order of preference):* 1. *Participatory rural appraisals conducted by project proponents,* 2. *Recent (<10 yr) peer-reviewed scientific literature in the reference region,* 3. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region, or* 4. *Recent (<10 yr) non peer-reviewed reports by local organizations.*	[m^3 yr^{-1}]
(8)	$DT_{baseline}$	m	Annually extracted volume of timber for domestic and local use, roundwood. *Measure from (in order of preference):* 1. *Participatory rural appraisals conducted by project proponents;* 2. *Recent (<10 yr) peer-reviewed scientific literature in the reference region,* 3. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region, or* 4. *Recent (<10 yr) non peer-reviewed reports by local organizations.*	[m^3 yr^{-1}]
(9), (11)-(20)	ΔC_{DF}	c	Total carbon loss due to deforestation. *Calculate using Equation (9).*	[Mg C yr^{-1}]
(10), (11)-(20)	ΔC_{DF}	c	Total carbon loss due to degradation. *Calculate using Equation (10).*	[Mg C yr^{-1}]
(9), (10), (106), (62), (63)	$nrDrivers$	p	Number of drivers of deforestation or forest degradation. *Select using the procedure in section II.1.3, "Analyze the Agents and Drivers of Deforestation".*	count
(9)	$proportion_{DF}(d)$	c	Proportion of the gradual carbon loss that leads to deforestation due to driver d. *Select this value from Table 11, depending on the conditions in this table.*	proportion
(10), (107)	$proportion_{DG}(d)$	c	Proportion of the gradual carbon loss that leads to forest degradation due to driver d. *Select this value from Table 11, depending on the conditions in this table.*	proportion
(11)-(19), (60)	$contribution_{DF}(i)$	c	Relative contribution of driver i to the total deforestation. *Calculate using Equations (11)-(19).*	proportion
(12)-(20), (61)	$contribution_{DG}(i)$	c	Relative contribution of driver i to the total forest degradation. *Calculate using Equations (12)-(20).*	proportion
(21)	N	c	Maximum possible number of sample plots in the project area. *Calculate using Equation (21).*	count

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(21), (38), (39), (89), (90)	$size_{projectArea}$	p	Combined size of all strata, e.g. the area of the total project area. *Depending on project conditions.*	[ha]
(21), (30), (32)	AP	p	Sample plot size (constant for all strata). *Select based on 2003 IPCC HPH-LULUCF, local biomass inventory protocols or Pearson et al. (2006).*	[ha]
(21)	N_i	c	Maximum possible number of sample plots in stratum i. *Calculate using Equation (21).*	count
(21), (41)	$area(i,t)$	m	Total area of class or stratum $\boldsymbol{i}$ during time t. *Calculate based on a (preliminary) stratification and classification from a remote sensing analysis detailed in section.*	[ha]
(22), (23)	E_i	c	Allowable error of the aboveground tree biomass. *Calculate using Equation (22).*	[Mg DM ha^{-1}]
(22)	Q_i	e	Approximate average value of the aboveground tree biomass of class or stratum i. *Estimate from literature according to the procedure in II.1.4.2.*	[Mg DM ha^{-1}]
(22)	p	p	Desired level of precision. *Selected by project proponents, must be smaller than 10%.*	proportion
(23)	n	c	Sample size (total number of sample plots required) in the project area. *Calculate using Equation (23).*	count
(23), (27)	n_i	c	Sample size for stratum i. *Calculate using Equation (23).*	[ha]
(23)	α	p	Minimal confidence level for the biomass stock density measured with a biomass inventory. *Select a value of at least 95%.*	proportion
(23)	st_i	e	Expected standard deviation of the aboveground biomass of class or stratum i. *Estimate from literature or preliminary measurements according to the procedure in II.1.4.2.*	[Mg DM ha^{-1}]
(23)	$cost_i$	p	Cost to sample stratum i. *Select according to the estimated costs of sampling in a certain forest stratum. Set to 1 if costs are identical for all strata.*	[-]
(24), (25)	$\boldsymbol{B_{plot\text{-}wise}(i,p)}$	c	Total biomass stock density of plot p within LULC class or forest stratum i. *Calculate using Equation (24).*	[Mg DM ha^{-1}]
(24), (30), (31)	$\boldsymbol{B_{AG,plot\text{-}wise}(i,p)}$	c	Aboveground tree biomass stock density of plot $\boldsymbol{p}$ within LULC class or forest stratum $\boldsymbol{i}$. *Calculate using Equation (30).*	[Mg DM ha^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(24), (31)	$B_{BG,plot\text{-}wise}(i,p)$	c	Belowground tree biomass stock density of plot p within LULC class or forest stratum i. *Calculate using Equation (31).*	[Mg DM ha^{-1}]
(24), (32)	$B_{LDW,plot\text{-}wise}(i,p)$	c	Lying dead-wood biomass stock density of plot p within LULC class or forest stratum i. *Calculate using Equation (32).*	[Mg DM ha^{-1}]
(24)	$B_{SDW,plot\text{-}wise}(i,p)$	c	Standing dead-wood biomass stock density of plot p within LULC class or forest stratum i. *Calculate using the "standing dead wood" procedure explained in section II.1.4.5.*	[Mg DM ha^{-1}]
(25), (29)	$B(i)$	c	Average total biomass stock density of LULC class or forest stratum i. *Calculate using Equation (23).*	[Mg DM ha^{-1}]
(26), (27)	$stdev(B(i))$	c	Standard deviation of the total biomass stock density of LULC class or forest stratum i. *Calculate using Equation (26).*	[Mg DM ha^{-1}]
(27)	$stderr(B(i))$	c	Standard error of the average of the total biomass stock density of LULC class or forest stratum i. *Calculate using Equation (27).*	[Mg DM ha^{-1}]
(28), (34)	$HWCI(B(i))$	c	Half-width of the confidence interval around the average of the total biomass stock density of LULC class or forest stratum i. *Calculate using Equation (28).*	[Mg DM ha^{-1}]
(30)	$nrTrees(i,p)$	m	Number of trees in sample plot p of LULC class or forest stratum i. *Measure in sampling plots; count trees only if the tree is above a certain minimum DBH, see* $DBH(t,i,p)$ parameter.	count
(30)	$f_{allometric}(y)$	d	Allometric relationship to convert DBH into biomass. *Use the following hierarchy to select the most appropriate allometric equation.* 1. *Allometric equations developed by project proponents* 2. *Allometric equations developed locally by groups other than project proponents* 3. *Allometric equations developed for forest types that are similar to the ones in the project as found in found in Appendix C of Pearson et al. (2005), or Tables 4.A.1. and 4.A.2. of the GPG LULUCF.*	equation
(30)	$DBH(t,i,p)$	m	DBH of tree t within plot p of LULC class or forest stratum i. *Measure in sampling plots if the tree is above a certain minimum DBH. Typically measured 1.3 m above the ground. The minimum value varies on tree species and climate. In arid climates, the minimum DBH may be as small as 2.5 cm, whereas it could be up to 10 cm for humid climates.*	[cm]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(30), (32)	$\boldsymbol{\theta(i,p)}$	m	Slope of the land of plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$ (see section 8 in Pearson et al., 2005). *Measure in sampling plots.*	degrees
(31)	$\boldsymbol{f_{belowground}(y)}$	d	Relationship between aboveground and belowground biomass, such as a root-to-shoot ratio. *Use (in order of preference).* *1. A relationship calculated from destructive sampling data obtained within the project area.* *2. A relationship obtained from the local/national studies that closely reflect the conditions of the project activity.* *3. Equations under section 8.2 of Pearson et al., 2005, or standard root-to-shoot ratios as found in Table 4.4 of the IPCC GPG-LULUCF 2003, and adapted by Brown et al., 2007.*	equation
(32)	$\boldsymbol{nrDecompClasses}$	p	Number of decomposition classes. *Select the appropriate decomposition class. If no information is recorded, use a default value of 3.*	1=sound 2=intermediate 3=rotten
(32)	$\boldsymbol{D(d,i,p)}$	m	Sum of diameters in biomass class $\boldsymbol{d}$ of sampling plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. *Measure in sampling plots.*	[m]
(32)	$\boldsymbol{L}$	p	Length of the transect. *Use the value selected in standard operations procedure for field sampling for the line intersect method (Harmon and Sexton, 1996). The standard length of this is 50 m.*	[m]
(32)	$\boldsymbol{\rho_{DW}(d)}$	m	Basic density of dead wood in the density class d. *Use wood densities from GPG LULUCG Tables 3A.1.9-1 and 3A.1.9-2.*	[kg.DM m^{-3}]
(33)	$EF_{bio}(classStratum1 \rightarrow classStratum2)$	c	Emission factor for change from LULC class or forest stratum 1 to 2. *Calculate using Equation (33).*	[MTCO2e ha^{-1}],
(35)	$EF_{fire}(classStratum1 \rightarrow classStratum2)$	c	Total GHG emission from biomass burning. *Calculate using Equation (35).*	[MTCO2e ha^{-1}]
(35)	C_{min}	c	Minimal carbon stock density of all forest strata. *Calculate using the "Minimal carbon stock density of all forest strata" procedure explained in section II.1.4.6.2.*	[MT C ha^{-1}]
(35)	F	c	Relative importance of fire in the total deforestation during the historical reference period. *Calculate using* $\frac{L_2}{\Delta C_{DF}+\Delta C_{DG}}$ *from section II.1.3.2.*	proportion
(35), (69), (77), (78), (99), (103)	GWP_{N2O}	d	Global Warming Potentials for N_2O. *Use the IPCC default value of 310 for the first commitment period.*	[-]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(35), (77), (98), (101), (102)	GWP_{CH4}	d	Global Warming Potentials for CH_4. *Use the IPCC default value of 21 for the first commitment period.*	[-]
(35), (69), (77)	ER_{N2O}	d	Emission ratios for N_2O. *Use the IPCC default value of 0.007, see Table 3A.1.15 in IPCC GPG-LULUCF 2003.*	proportion
(35), (77)	ER_{CH4}	d	Emission ratios for CH_4. *Use the IPCC default value of 0.012, see Table 3A.1.15 in IPCC GPG-LULUCF 2003.*	proportion
(35), (69), (77)	r	d	Carbon-to-Nitrogen ratio of the wood. *Use (in order of preference):* 1. *A measured value based on leaf litter analyses,* 2. *A conservative value of 100.*	proportion
(36)	$D_{baselineScenario,DF,referenceRegion}(t)$	c	Rate of deforestation within the reference region for year t of the crediting period. *Calculate using Equation (36).*	[ha yr^{-1}]
(37)	$D_{baselineScenario,DG,referenceRegion}(t)$	c	Rate of forest degradation within the reference region for year t of the crediting period. *Calculate using Equation (37).*	[ha yr^{-1}]
(36)	a_{DF}	c	Intercept of the linear relationship between time and deforestation rate in the reference region during the historical reference period. *Calculate using the procedure explained in section II.1.5.1.*	[ha yr^{-1}]
(37)	a_{DG}	c	Intercept of the linear relationship between time and forest degradation rate in the reference region during the historical reference period. *Calculate using the procedure explained in section II.1.5.1.*	[ha yr^{-1}]
(36)	b_{DF}	c	Slope of the linear relationship between time and deforestation rate in the reference region during the historical reference period. *Calculate using the procedure explained in section II.1.5.1.*	[ha yr^{-2}]
(37)	b_{DG}	c	Slope of the linear relationship between time and forest degradation rate in the reference region during the historical reference period. *Calculate using the procedure explained in section II.1.5.1.*	[ha yr^{-2}]
(38), (64), (79), (96)	$D_{projectArea,baselineScenario,DF}(t)$	c	Baseline rate of deforestation within the project area for year t. *Calculate using Equation (38).*	[ha yr^{-1}]
(39), (65), (80), (96)	$D_{projectArea,baselineScenario,DG}(t)$	c	Baseline rate of forest degradation within the project area for year t. *Calculate using Equation (39).*	[ha yr^{-1}]
(38), (39)	$size_{referenceRegion}$	p	Total size of the reference region. *Select the size of the reference region based on the size of the project area and the procedure in section II.1.1.2.*	[ha]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(40), (41)	$RFRGrate(CS_1 \rightarrow CS_2)$	c	Relative annual reforestation and regeneration rate for the transition from class or stratum 1 to 2. *Calculate using Equation (40).*	[ha yr^{-1}]
(40)	$\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)$	m	Area of transition from LULC class or forest stratum 1 to 2 from time 1 to 2 during the historical reference period. *Calculate based on the remote sensing-based classification and stratification procedures detailed in section II.1.2.5.*	[ha]
(40)	$area_{historical}(CS_1, t_1)$	m	Total area of LULC class or forest stratum 1 during time 1. *Calculate based on the remote sensing-based classification and stratification procedures detailed in section II.1.2.5.*	[ha]
(42)-(59)	$effectiveness_{DF}(a, d)$	e	The relative effectiveness of project action a in reducing the deforestation caused by driver d. *This amount is dependent on an estimate of how effective project activities will be based on the allocated funds, the capacity of implementing organization, and the motivation of participating communities.*	proportion
(42)-(59), (60), (61)	$effectiveness_{DG}(a, d)$	e	The relative effectiveness of project action a in reducing the forest degradation caused by driver d. *This amount is dependent on an estimate of how effective project activities will be based on the allocated funds, the capacity of implementing organization, and the motivation of participating communities.*	proportion
(60), (106), (81), (96)	$RelativeDriverImpact_{DF}(t, d)$	c	Relative impact of a driver $\boldsymbol{d}$ on deforestation for year t of the crediting period (dimensionless). *Calculate using Equation (60).*	proportion
(61), (82), (96)	$RelativeDriverImpact_{DG}(t, d)$	c	Relative impact of a driver $\boldsymbol{d}$ on forest degradation for year t of the crediting period (dimensionless). *Calculate using Equation (61).*	proportion
(62), (64),	$RelativeProjectImpact_{DF}(t)$	c	Impact of all project activities on deforestation relative to the baseline deforestation and forest degradation rates during year t. *Calculate using Equation (62).*	proportion
(63), (65)	$RelativeProjectImpact_{DG}(t)$	c	Impact of all project activities on forest degradation, relative to the baseline deforestation and forest degradation rates during year t. *Calculate using Equation (63).*	proportion
(60), (61)	$nrActivities$	p	Total number of project activities. *This amount is dependent on the project activities selected by the project participants.*	count

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(60), (61)	$rate(a, d)$	e	Adoption rate or relative degree of activity for activity a during year t. A value of 100% indicates that the activity cannot be more efficient in reducing deforestation or forest degradation than estimated. *This amount is dependent on the implementation of the project activities selected by the project participants. Assume that some time is required to train local communities before full efficiency of project activities is reached. Integrate the phased spending of funds for project activities, if relevant.*	proportion
(64), (89)	$D_{projectArea,projectScenario,DF}(t)$	c	Rate of deforestation within the project area for year t under the project scenario. *Calculate using Equation (64).*	[ha yr^{-1}]
(65), (90)	$D_{projectArea,projectScenario,DG}(t)$	c	Rate of forest degradation within the project area for year t under the project scenario. *Calculate using Equation (65).*	[ha yr^{-1}]
(66), (67), (108)	$E_{fencing}$	c	Annual GHG emissions from boundary poles and fencing. *Calculate using Equation (67).*	[MTCO2e yr^{-1}]
(66), (68), (108)	$E_{vehicle}$	c	Annual GHG emissions from fuel use for vehicles used for implementation of REDD project activities (e.g., patrolling, transportation of materials and laborers, machinery to implement assisted natural regeneration activities). *Calculate using Equation (68).*	[MTCO2e yr^{-1}]
(66), (69), (108)	$E_{fireBreaks}$	c	Annual GHG emissions from implementation of fire-preventing actions as REDD project activities. *Calculate using Equation (69).*	[MTCO2e yr^{-1}]
(67)	NRP	e	Number of fence posts installed per year. *This amount is dependent on the project activities selected by the project participants. This value can be estimated ex-ante by dividing the total project perimeter by the average distance between wood posts from field observations.*	[yr^{-1}]
(67)	$FNRP$	e	Fraction of posts from off-site non-renewable sources. *Record the sources of the wood posts that will be used by the project.*	proportion
(67)	APV	e	Average volume of per wood posts. *Estimate by measuring the dimensions of the wood posts used for fencing.*	[m^3]
(67)	BEF_2	d	Biomass expansion factor for converting volumes of extracted round wood to total above-ground biomass including bark. *See IPCC GPG-LULUCF 2003 Table 3A.1.10.*	proportion
(68)	$nrFuel$	p	Number of fuel types used (diesel, gasoline, natural gas, propane, etc.) *This amount is dependent on the project activities selected by the project participants.*	count

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(68)	$FC(i)$	e	Estimated annual consumption of fuel type i [liters yr^{-1}]. *This amount is dependent on the project activities selected by the project participants. In case of vehicles, this can be estimated by multiplying the distance traveled by the fuel efficiency of the vehicle. Estimate the following categories of fuel consumption separately:* • *Fuel used for the installation of fencing.* • *Fuel used for forest patrolling.* • *Fuel used to transport laborers, seedlings, and material for ANR activities.* • *Fuel used during agricultural intensification.* • *Fuel used during fire prevention activities.*	[l km^{-1}]
(68)	$\rho_{fuel}(i)$	d	Standard density of fuel i. *Use standard density values of 0.737 kg l^{-1} for gasoline and 0.85 kg l^{-1} for diesel fuel.*	[kg l^{-1}].
(68)	$NCV(i)$	d	Net caloric value of fuel i. *Use values from IPCC GPG 2006 guidelines for Energy (Table 1.2) if no regional estimates are available. The most specific and conservative values should be used.*	[TJ Gg^{-1}]
(68)	$EF_{fuel,CO2}(i)$	d	CO_2 emission factor for fuel type i. *Use values from IPCC GPG 2006 guidelines for Energy (Table 3.2.1) if no regional estimates are available. The most specific and conservative values should be used.*	[kg CO_2 Gg^{-1}]
(69)	$nrFireClasses$	p	Number of forest strata in which fire breaks were installed. *The project proponents must select in which forest strata fire prevention measures will be implemented.*	count
(69)	$area_{biomassLoss}(i)$	m	Total annual area of forest stratum i that was cleared. *This amount is dependent on the fire prevention activities selected by the project participants.*	[ha yr^{-1}]
(69)	$area_{fireBiomassLoss}(i)$	m	Annual area of forest stratum i that was cleared by using controlled burning. *This amount is dependent on the fire prevention activities selected by the project participants.*	[ha yr^{-1}]
(70)	$C_{ANR}(t)$	c	Net anthropogenic greenhouse gas removals due to biomass increase in assisted natural regeneration. *Calculate using Equation (70).*	[MTCO2e]
(70), (71)	$\Delta C_{ANR}(t)$	c	Annual change in carbon stocks in all selected carbon pools due to ANR for year t. *Calculate using Equation (71).*	[Mg C yr^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(70), (75), (108)	$E_{biomassLoss,ANR}(t)$	c	Increase in CO_2 emissions from loss of existing woody biomass due to site-preparation (including burning), and/or to competition from forest (or other vegetation) planted as part of the ANR activities. *Calculate using Equation (75).*	[MTCO2e]
(70), (74), (76)	$GHG_{E,ANR}(t)$	c	Increase in GHG emissions as a result of the implementation of the proposed ANR activities during year t. *Calculate using Equation (76).*	[MTCO2e]
(70), (73)	$\Delta C_{ANR,BSL}(t)$	c	Baseline greenhouse gas emissions or sources for year t. *Calculate using Equation (73).*	[Mg C yr^{-1}]
(70)	$LK_{ANR}(t)$	c	Total GHG emissions due to leakage for year t. *This should not be calculated. Leakage from ANR is included in the total leakage, as explained in section II.3. Parameter is only added to ensure compatibility with AR-ACM0001 version 3.*	[Mg C yr^{-1}]
(71)	$nrStrata$	p	Number of forest strata. *The number of forest strata is dependent on the stratification procedure employed by the project proponents.*	count
(72)	$area_{projectAreaWithANR,projectScenario}(t,i)$	p	Amount of land on which ANR activities are planned under the baseline scenario for year $\boldsymbol{t}$ and in stratum i. *The area on which ANR activities are proposed is dependent on the ANR management plan designed by the project proponents.*	[ha]
(75)	$area_{biomassLoss,ANR}(t,i)$	p	Area of biomass removed within ANR stratum i during year t. *This amount is dependent on the ANR project activities selected by the project participants.*	[ha]
(76), (77), (108)	$E_{fire,ANR}(t)$	c	CH_4 and N_2O emissions of burning of existing woody biomass for land preparation of assisted natural regeneration activities during year t. *Calculate by using Equation (77).*	[$MTCO_2e$ yr^{-1}].
(76), (78), (108)	$E_{fertilization,ANR}(t)$	c	GHG emission from fertilization for land preparation of assisted natural regeneration activities during year t. *Calculate using Equation (78).*	[$MTCO_2e$ yr^{-1}].
(77)	$area_{fireBiomassLoss,ANR}(t,i)$	p	Area of biomass removed using controlled burning within ANR stratum i during year t. *This amount is dependent on the project activities selected by the project participants.*	[ha]
(78), (99)	$EF_{N\text{-}inputs}$	d	Emission factor for emissions from N inputs. *Use the default emission factor of 1.25 % of applied N as noted in IPCC GPG 2000.*	proportion

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(78)	$N_{synthetic,ANR}(t)$	p	Total amount of synthetic fertilizer for land preparation of ANR activities, adjusted for volatilization as NH_3 and NOx during year t. *This amount is dependent on the project activities selected by the project participants.*	[Mg N ha^{-1} yr^{-1}]
(78), (99)	f_{GASF}	d	Fraction that volatilizes as NH_3 and NOx for synthetic fertilizers (dimensionless). *Use the default value for the fraction of synthetic fertilizer nitrogen that is emitted as NOx and NH_3 of 0.1 as noted in the 1996 IPCC Guideline.*	proportion
(78)	$N_{organic,ANR}(t)$	p	Total amount of organic fertilizer for land preparation of ANR activities during year t. *This amount is dependent on the project activities selected by the project participants.*	[Mg N ha^{-1} yr^{-1}]
(78), (99)	f_{GASM}	d	Fraction that volatilizes as NH_3 and NOx for organic fertilizers (dimensionless). *Use the default values 0.2 from the 1996 IPCC Guideline.*	proportion
(79), (91)	$\Delta D_{LK,DF}(t)$	c	Leakage-induced increase in deforestation rate for year t of the crediting period. *Calculate using Equation (79).*	[ha yr^{-1}]
(80), (92)	$\Delta D_{LK,DG}(t)$	c	Leakage-induced increase in forest degradation rate for year t of the crediting period. *Calculate using Equation (80).*	[ha yr^{-1}]
(79), (81)	$RelativeLeakageImpact_{DF}(t)$	c	Total relative impact of leakage on the decrease in GHG emissions due to project activities from deforestation for year $\boldsymbol{t}$ of the crediting period. *Calculate using Equation (81).*	[-]
(80), (82)	$RelativeLeakageImpact_{DG}(t)$	c	Total relative impact of leakage on the decrease in GHG emissions due to project activities from forest degradation for year t of the crediting period. *Calculate using Equation (82).*	[-]
(82)	$nrCDrivers$	m	Number of geographically constrained drivers. *Select based on the analysis of the drivers of deforestation and forest degradation.*	count
(81), (82), (83)-(88), (96)	$leakage(d)$	e	leakage cancellation rate for avoiding deforestation/degradation of driver $\boldsymbol{d}$ *Calculate using the "leakage cancellation rate" procedure in section II.3.2.1.*	[-]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(83)	$FW_{baseline}$	m	Biomass (dry matter) of fuel-wood collected by project participants under the baseline scenario. *Select based on (in order of preference):* *(1) Social appraisals in the project area before start of the crediting period.* *(2) Peer-reviewed literature from a similar area as the project area.*	[m^3 yr^{-1}]
(83)	$FW_{project}$	c	Biomass (dry matter) of fuel-wood collected by project participants under the project scenario. *Calculate using Equation (84).*	[m^3 yr^{-1}]
(83)	$FW_{allowed}$	p	Biomass (dry matter) of allowed fuel-wood collection in the project area under the project scenario. *Use value of allowed fuel-wood collection volume fixed in management plan.*	[m^3 yr^{-1}]
(84)	$nrfuelWoodReductionActions$	p	The number of project activities that reduce the need for fuel-wood. E.g., introduction of fuel-efficient wood-stoves, mosquito nets for livestock, biogas plants. *This amount is dependent on the project activities selected by the project participants.*	count
(84), (107)	$adoption(i)$	e	Adoption rate of project activity i which reduces fuel-wood consumption. *The adoption rate must be estimated by the project participants based on a prediction of the willingness of local communities to adopt the alternative practice.*	(dimensionless)
(84), (107)	$efficiency(i)$	e	Rate at which project activity i reduces fuel-wood consumption. *Use a value from literature, manufacturer of the device (if relevant).*	(dimensionless)
(85)	$\Delta area_{settlement,baseline}$	m	Area that would be converted to settlements by participating communities under the baseline scenario. *Determine this value by (in order of preference):* *(1) Remote sensing analysis in the project area before start of the crediting period.* *(2) Social appraisals in the project area before start of the crediting period.* *(3) Peer-reviewed literature.* *(4) Country experts.*	[ha yr^{-1}]
(85)	$\Delta area_{settlement,project}$	e	Area that will be converted to settlements by participating communities under the project scenario. *Estimate the area that will be converted to cropland based on an understanding of the area required per household dwelling when participatory land use plans are in place and the anticipated population increase.*	[ha yr^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(85)	$\Delta area_{settlement,allowed}$	p	Area that will be converted to settlements after within the project area under the project scenario. *This amount is selected by the project participants and fixed in a management plan.*	[ha yr^{-1}]
(86)	$\Delta area_{cropLand,baseline}$	m	Area that would be converted to cropland by participating communities under the baseline scenario. *Determine this value by (in order of preference):* *(1) Remote sensing analysis in the project area before start of the crediting period* *(2) Social appraisals in the project area before start of the crediting period* *(3) Peer-reviewed literature* *(4) Country experts.*	[ha yr^{-1}]
(86)	$\Delta area_{cropLand,project}$	e	Area that will be converted to cropland by participating communities under the project scenario. *Estimate the area that will be converted to cropland based on an understanding of the cropland area required per household when support for agricultural intensification is provided and the anticipated population increase.*	[ha yr^{-1}]
(86)	$\Delta area_{cropLand,allowed}$	p	Area that will be converted to cropland after within the project area under the project scenario. *This amount is selected by the project participants and fixed in a management plan.*	[ha yr^{-1}]
(89), (91)	$D_{leakageArea,baselineScenario,DF}(t)$	c	Baseline rate of deforestation within the leakage area for year t of the crediting period. *Calculate using Equation (89).*	[ha yr^{-1}]
(90), (92)	$D_{leakageArea,baselineScenario,DG}(t)$	c	Baseline rate of forest degradation within the leakage area for year t of the crediting period. *Calculate using Equation (90).*	[ha yr^{-1}]
(89), (90)	$size_{leakageArea}$	p	Size of the leakage area. *Select based on the procedure in section II.3.2.2.*	[ha]
(96)	EF_{max}	c	The most negative emission factor. Calculate by comparing all emission factors from Table 13.	[MTCO2e]
(96)	$nrUDrivers$	c	Number of drivers that are geographically unconstrained. *Use Table 14 to select which drivers are geographically unconstrained.*	count
(97), (98), (108)	$\Delta E_{rice}(t)$	c	Annual difference in GHG emissions due to increased use of flooded rice production systems as agricultural intensification measures for year t of the crediting period. *Calculate using Equation (98).*	[MTCO2e]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(97), (99), (108)	$\Delta E_{fertilization}(t)$	c	Annual difference in GHG emissions due to increased use of N fertilizer as an agricultural intensification measure for year $\boldsymbol{t}$ of the crediting period. *Calculate using Equation (99).*	[MTCO2e]
(97), (100), (108)	$\Delta E_{livestock}(t)$	c	Annual difference in GHG emissions by enteric fermentation and manure management from increased animal stocking rates as an agricultural intensification measure for year t of the crediting period. *Calculate using Equation (100).*	[MTCO2e]
(98)	$nrRiceCultivationClasses$	p	Number of rice cultivation conditions class which are promoted as agricultural intensification measures. A rice cultivation condition class is a combination of ecosystem, water regimes, type and amount of organic amendments, and other conditions under which CH_4 emissions from rice may vary. *Value is dependent on project design and is therefore selected by project proponents.*	count
(98)	$EF_c(i)$	d	Baseline emission factor for continuously flooded fields without organic amendments. *Use the IPCC default factor of 1.30 kg CH_4 ha^{-1} day^{-1}.*	[kg CH_4 ha^{-1} day^{-1}]
(98)	$SF_w(i)$	d	Scaling factor to account for the differences in water regime during the cultivation period for conditions i. Select from Table 5.12.	factor
(98)	$SF_p(i)$	d	Scaling factor to account for the differences in water regime in the pre-season before the cultivation period for conditions i. *Select from Table 5.13.*	factor
(98)	$SF_o(i)$	d	Scaling factor for type and amount of organic amendment applied for conditions i. *Select from Table 5.14.*	factor
(98)	$SF_{s,r}(i)$	d	Scaling factor should vary for both type and amount of organic amendment applied for conditions i. *Select from Table 5.14.*	factor
(98)	$\Delta t_{rice}(i)$	m	Cultivation period of rice for conditions i during a cultivation year. *Estimate from average farming practices near the project area.*	[days yr^{-1}]
(98)	$\Delta area_{rice}(t,i)$	p	Difference in harvested area of rice for conditions i between project scenario and baseline scenario for year t. *Value is dependent on project activities and fund allocation. Estimate based on the anticipated success of agricultural intensification programs.*	[ha yr^{-1}]
(99)	$nrfertilizerClasses$	p	Number of cropping systems in which fertilizer is promoted as agricultural intensification measure. *Value is dependent on project design and is therefore selected by project proponents. Most likely, only 1 cropland LULC class will exist.*	count

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(99)	$\Delta area_{fertilized}(t,i)$	e	Increase in area of cropping system i between project scenario and baseline scenario during year t of the crediting period. *Estimate based on expected adoption rates.*	[ha]
(99)	$N_{synthetic}(i)$	m	Average per hectare annual amount of synthetic fertilizer nitrogen applied within the LULC class i. *Estimate from average farming practices near the project area.*	[Mg N ha^{-1} yr^{-1}]
(99)	$N_{organic}(i)$	m	Average per hectare annual amount of organic fertilizer nitrogen applied within the LULC class i. *Estimate from average farming practices near the project area.*	[Mg N ha^{-1} yr^{-1}]
(100), (101)	$\Delta E_{enteric,CH4}(t)$	c	Increases in CH_4 emissions from enteric fermentation due to increases in stocking rates for year t of the crediting period. *Calculate using Equation (101).*	[MTCO2e]
(100), (102)	$\Delta E_{manure,CH4}(t)$	c	Increases in CH_4 emissions from manure management due to increases in livestock stocking rates for year t of the crediting period. *Calculate using Equation (102).*	[MTCO2e]
(100), (103)	$\Delta E_{manure,N2O}(t)$	c	Increases in N_2O emissions from manure management due to increases in stocking rates for year t of the crediting period. *Calculate using Equation (103).*	[MTCO2e]
(101)	EF_1	d	Enteric CH_4 emission factor for livestock group. *Use default values from Tables 10.10 and 10.11 in the 2006 IPCC Guidelines for AFOLU.*	[kg CH_4 $head^{-1}$ yr^{-1}]
(101), (102), (103)	$\Delta P(t)$	m	Difference in equivalent number of forage-fed livestock in LULC between project scenario and baseline scenario. *Estimate based on current number of livestock heads and expected adoption rates of increased stocking rates as agricultural intensification measures.*	[heads]
(102)	EF_2	d	Manure management CH_4 emission factor for the livestock group. *Use default emission factors presented in table 10.14-10.16 of IPCC 2006 Guidelines for AFOLU. These emission factors represent those for a range of livestock types and associated management systems, by regional management practices and temperature. When selecting a default factor, be sure to consult the supporting tables in Annex 10A.2 of IPCC 2006 Guidelines for AFOLU, for the distribution of manure management systems and animal waste characteristics used to estimate emissions. Select an emission factor for a region that most closely matches the circumstances of the livestock that are fed forage from the project area.*	[kg CH_4 $head^{-1}$ yr^{-1}]
(103), (104)	$\Delta E_{manure,N2O,direct}(t)$	c	Difference in annual GHG emissions from direct N_2O emissions from manure management. *Calculate using Equation (104).*	[MTCO2e yr^{-1}]

Used in Eq.	Parameter	Source	Description and Procedure	Unit
(103), (105)	$\Delta E_{manure,N2O,indirect}(t)$	c	Difference in annual GHG emissions from indirect N_2O emissions from manure management *Calculate using Equation (105).*	[MTCO2e yr^{-1}]
(103)	N_{excr}	d	Annual average N excretion per livestock head determined for the forage-fed livestock group supported by the project. *Use the default nitrogen excretion rates presented in Table 10.19 of IPCC 2006 Guidelines for AFOLU.*	[kg N $head^{-1}$ yr^{-1}]
(103)	EF_3	d	Emission factor for N_2O emissions from manure management for the main livestock group. *Use the default emission factors presented in Table 10.21 and Table 11.3 of the IPCC 2006 Guidelines for AFOLU.*	factor
(103)	f_{gas}	d	Fraction of managed livestock manure nitrogen that volatilizes as NH_3 and NOx in the manure management phase. *Use the default values presented in the Table 10.22 of the IPCC 2006 Guidelines.*	factor
(103)	EF_4	d	Emission factor for N_2O emissions from atmospheric deposition of forage-sourced nitrogen on soils and water surfaces. *Use the IPCC default factor of 0.01 as noted in the IPCC 2006 Guidelines for AFOLU.*	factor
(107)	$WS(t)$		Annual emission reductions from introducing fuel-efficient wood-stoves.	[MTCO2e]
(108)	$relativeContribution(E_i)$	c	Relative contribution of each source of GHG emissions i to the sum of GHG emissions. *Calculate using Equation (108).*	proportion
(108)	$nrEmissions$	p	Total number of sources of GHG emissions considered. *Value is dependent on project design and is therefore selected by project proponents.*	count

Section III: Monitoring Methodology Description

This methodology requires the following monitoring components for calculating actual NERs

- Monitoring of deforestation drivers, project activities and emission sources related to REDD project activities inside and outside of the project area.
- Monitoring LULC class and forest strata transitions in the project area, leakage area, and reference region using remote-sensing technologies, and validated with ground-truthing data.
- Monitoring carbon stock densities in LULC classes and forest strata.
- Monitoring carbon stock increases in the area on which ANR are performed.
- Monitoring of natural disturbances.

A monitoring report is produced which contains all of the information above, and which outlines the calculations for actual NERs generated. This monitoring report is the basis for verification by VCS-accredited verifiers. The actual VCUs are released upon verification and positive evaluation of a monitoring. The VCS requires that verification takes place minimally every five years. Project proponents may choose to seek verification more frequently, especially in the beginning of the crediting period. The PD must contain a fixed time schedule of when verification will be sought during the full duration of the crediting period.

III.1 Overview of the Data that Must be Recorded and Monitored

III.1.1 Monitoring of Deforestation Drivers, Project Activities and Emission Sources

The table below contains a list of all the information to be recorded about the actions that occurred in the project and leakage areas, depending on the project activities implemented. The abbreviation AO indicates "as occurring", indicating that project activities must be recorded as they happen.

Duly record and justify any deviation from the planned activities as described in the PD. Record any activity that may cause an increase of GHG emissions, which was unforeseen in the PD.

The same procedure as outlined in section II.1.4.5 should be followed for on-going monitoring of already established permanent forest sampling plots. It is crucial that the procedure used to perform the biomass inventory is consistent throughout the project duration. The Standard Operations Procedure for biomass inventory developed in section II.1.4.5 should be meticulously followed. The results of the biomass inventory should be analyzed and checked for consistency and the emission factors in Table 13 should be updated following section II.1.4.6.1.

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Household count	Number of households in the project area. *Estimate using official records.*	count	5 yr
	Household size	Average size of a household in the project area. *Estimate using social appraisals.*	count	5 yr
(1), (73)	$NAI(i)$	Net annual increment due to natural regeneration and succession for the "from" class of transition i, as reported in section II.1.4.2. *Calculate based on the biomass inventory (see "monitoring" section).*	[Mg DM ha^{-1} yr^{-1}]	AO
(1)	$area_{projectAreaWithANR,baselineScenario}(t,i)$	Size of strata i within the project area on which ANR activities are proposed for year t. *Calculate based on the modeling procedure referred to in section II.1.5.4.*	[ha]	
(1)	$\Delta area_{projectAreaWithANR,baselineScenario}(t,i)$	Hectares undergoing transition i within the ANR area under the baseline scenario for year t. *Calculate based on the modeling procedure referred to in section II.1.5.4.*	[ha yr^{-1}]	
(3)	$FW_{baseline}$	Annual volume of fuelwood gathering in the baseline scenario. *Measure from (in order of preference):* *1. Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *2. Recent (<10 yr) peer-reviewed scientific literature in the reference region.* *3. Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.*	[m^3 yr^{-1}]	5 yr
(4)	$area_{baseline,fire}(i)$	Forest area in the project area affected by disturbances from forest fires in forest stratum i. *Use the following sources (in order of preference):* *1. Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *2. Recent (<10 yr) peer-reviewed scientific literature in the reference region.* *3. Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.* *4. Expert opinion.*	[ha yr^{-1}]	5 yr

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
(5)	$\Delta area_{baseline,cropland}(i)$	Forest area converted from forest stratum i to cropland in the project area under baseline conditions at the start of the project. *Measure from (in order of preference):* *1. Remote sensing analyses in the reference region, see section II.1.2.5.* *2. Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *3. Recent (<10 yr) peer-reviewed scientific literature in the reference region.* *4. Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.*	[ha yr^{-1}]	5 yr
(6)	$\Delta area_{baseline,settlement}(i)$	Average forest area converted from forest stratum i to settlements in the reference region under baseline conditions. *Measure from (in order of preference):* *1. Remote sensing analyses in the reference region, see section II.1.2.5.* *2. Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *3. Recent (<10 yr) peer-reviewed scientific literature in the reference region.* *4. Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.*	[ha yr^{-1}]	5 yr
(7)	$IT_{baseline}$	Annually extracted volume of illegally harvested timber, roundwood. *Measure from (in order of preference):* *1. Participatory rural appraisals conducted by project proponents. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *2. Recent (<10 yr) peer-reviewed scientific literature in the reference region.* *3. Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.* *4. Recent (<10 yr) non peer-reviewed reports by local organizations.*	[m^3 yr^{-1}]	5 yr
	Timber price	Prices of timber on local markets. *Record during field survey.*	local currency	5 yr

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
(8)	$DT_{baseline}$	Annually extracted volume of timber for domestic and local use, roundwood. *Measure from (in order of preference):* 1. *Participatory rural appraisals conducted by project proponents.* 2. *Recent (<10 yr) peer-reviewed scientific literature in the reference region.* 3. *Recent (<10 yr) peer-reviewed scientific literature in an area similar to the reference region.* 4. *Recent (<10 yr) non peer-reviewed reports by local organizations.*	[m^3 yr^{-1}]	5 yr
(40), (41)	$area(i,t)$	Total area of class or stratum i during time t. *Calculate based on a (preliminary) stratification and classification from a remote sensing analysis detailed in section II.1.2.*	[ha]	5 yr
(30)	$\boldsymbol{nrTrees}(\boldsymbol{i},\boldsymbol{p})$	Number of trees in sample plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. *Measure in sampling plots; count trees only if the tree is above a certain minimum DBH, see* $\boldsymbol{DBH}(\boldsymbol{t},\boldsymbol{i},\boldsymbol{p})$ parameter**.**	count	5 yr
(30)	$\boldsymbol{DBH}(\boldsymbol{t},\boldsymbol{i},\boldsymbol{p})$	DBH of tree $\boldsymbol{t}$ within plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. *Measure in sampling plots if the tree is above a certain minimum DBH. Typically measured 1.3 m above the ground. The minimum value varies on tree species and climate. In arid climates, the minimum DBH may be as small as 2.5 cm, whereas it could be up to 10 cm for humid climates.*	[cm]	5 yr
(30), (32)	$\boldsymbol{\theta}(\boldsymbol{p},\boldsymbol{i})$	Slope of the land of plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$ (see section 8 in Pearson et al.**,** 2005). *Measure in sampling plots.*	degrees	5 yr
(32)	$\boldsymbol{D}(\boldsymbol{d},\boldsymbol{i},\boldsymbol{p})$	Sum of diameters in biomass class $\boldsymbol{d}$ of sampling plot $\boldsymbol{p}$ of LULC class or forest stratum $\boldsymbol{i}$. *Measure in sampling plots.*	[m]	5 yr
(40)	$\Delta area_{historical}(CS_1 \rightarrow CS_2, t_1 \rightarrow t_2)$	Area of transition from LULC class or forest stratum 1 to 2 from time 1 to 2 during the historical reference period. *Calculate based on the remote sensing-based classification and stratification procedures detailed in section II.1.2.*	[ha yr^{-1}]	5 yr
(40)	$area_{historical}(CS_1, t_1)$	Total area of LULC class or forest stratum 1 during time 1. *Calculate based on the remote sensing-based classification and stratification procedures detailed in section II.1.2.*	[ha]	5 yr
(67)	NRP	Number of fence posts installed per year. *This amount is dependent on the project activities selected by the project participants. Record during activity implementation.*	[yr^{-1}]	AO

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Fencing material	Material, type and source of the fences and poles used for boundary demarcation. *Record during activity implementation.*	narrative	AO
(67)	$FNRP$	Fraction of posts from off-site non-renewable sources. *Record during activity implementation.*	proportion	AO
(67)	APV	Average volume of per wood posts. *Estimate by measuring the dimensions of at least 30 poles or fence posts.*	[m^3]	AO
	Fencing installation labor	Labor hours that were needed to install and maintain boundary poles and fencing. *Record during activity implementation.*	[hrs]	AO
(68)	$FC(i)$	Estimated annual consumption of fuel type i [liters yr^{-1}]. *This amount is dependent on the project activities selected by the project participants. In case of vehicles, this can be estimated by multiplying the distance traveled [km] by the fuel efficiency of the vehicle. Record during activity implementation for the following categories:* • *fuel used for the installation of fencing* • *fuel used for forest patrolling* • *fuel used to transport laborers, seedlings, and material for ANR activities* • *fuel used during agricultural intensification* • *fuel used during fire prevention activities.*	[l km^{-1}]	AO
	Forest patrolling labor	Labor hours used for forest patrolling. *Record during activity implementation.*	[hrs]	AO
	Description of fire prevention measures	Provide information on fire prevention measures, including dates of implementation, type of activity, and location (lat/lon coordinates). *Record during activity implementation.*	text	AO
(69)	$area_{biomassLoss}(i)$	Total annual area of LULC class i that was cleared. *This amount is dependent on the fire prevention activities selected by the project participants. Record during activity implementation.*	[ha yr^{-1}]	AO
(69)	$area_{fireBiomassLoss}(i)$	Annual area of forest stratum i that was cleared by using controlled burning. *This amount is dependent on the fire prevention activities selected by the project participants. Record during activity implementation.*	[ha yr^{-1}]	AO

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
(83)	$FW_{baseline}$	Biomass (dry matter) of fuel-wood collected by project participants under the baseline scenario. *Select based on (in order of preference):* *(1) Social appraisals in the project area before start of the crediting period. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.* *(2) Peer-reviewed literature from a similar area as the project area.*	$[m^3\ yr^{-1}]$	5 yr
(84)	$adoption(i)$	Adoption rate of project activity i which reduces fuel-wood consumption. *The adoption rate must be estimated by the project participants based on social appraisals in the project area during the crediting period.*	proportion	5 yr
(84)	$efficiency(i)$	Rate at which project activity i reduces fuel-wood consumption. *The efficiency must be based on measurements of efficiency by the project proponents in at least 10 randomly selected households.*	proportion	5 yr
(85)	$\Delta area_{baseline,settlement}$	Area that would be converted to settlements by participating communities under the baseline scenario. *Determine this value by (in order of preference) remote sensing analysis in the reference region after the start of the crediting period.*	$[ha\ yr^{-1}]$	5 yr
(98)	$\Delta t_{rice}(i)$	Cultivation period of rice for conditions i during a cultivation year. *Value is dependent on project activities and fund allocation. Estimate based on participatory rural appraisals among the participating communities.*	$[days\ yr^{-1}]$	5 yr
		Description of agricultural intensification pilot projects, including • location of pilot projects of agricultural intensification practices • crop species and varieties used • Dates of planting, cultivation, harvesting for agricultural intensification practices • Costs of inputs (seed, fertilizer, etc.) for agricultural intensification practices. *Record during activity implementation.*	coordinates in shapefile	AO
	Fertilized cropland in reference region	Area of fertilized land cropland in the reference region. *Estimate using a combination of field survey and remote sensing analysis.*	[ha]	5 yr

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Fertilized cropland in leakage area	Area of fertilized land cropland in the leakage area. *Estimate using a combination of field survey and remote sensing analysis.*	[ha]	5 yr
	Fertilized cropland in project area	Area of fertilized land cropland in the project area. *Estimate using a combination of field survey and remote sensing analysis.*	[ha]	5 yr
(99)	$\Delta area_{fertilized}(t,i)$	Increase in area of cropping system i between project scenario and baseline scenario during year t of the crediting period. *Calculate based on areas of fertilized cropland in the leakage and project areas.*	[ha]	5 yr
(99)	$N_{synthetic}(i)$	Average per hectare annual amount of synthetic fertilizer nitrogen applied within the LULC class i. *Estimate from average farming practices near the project area using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[Mg N ha^{-1} yr^{-1}]	AO
(99)	$N_{organic}(i)$	Average per hectare annual amount of organic fertilizer nitrogen applied within the LULC class i. *Estimate from average farming practices near the project area using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[Mg N ha^{-1} yr^{-1}]	AO
	Yields under agricultural intensification	Harvested yield for agricultural intensification practices. *Estimate using participatory rural appraisals.*	metric ton ha^{-1}	AO
	Agricultural outreach activity description	Provide dates and reports of demonstration meetings or agricultural outreach and extension activities for agricultural intensification practices. *Record during activity implementation. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	narrative	AO
	Livestock count owned by communities	Equivalent number of forage-fed livestock in all relevant LULC classes owned by participating communities. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[heads per household]	5 yr
	Livestock count in leakage area	Equivalent number of forage-fed livestock in all relevant LULC classes owned by non-participating communities in the leakage area. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[heads per household]	5 yr

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Livestock count in reference region	Equivalent number of forage-fed livestock in all relevant LULC classes owned by non-participating communities in the reference region. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[heads per household]	5 yr
(101), (102), (103)	$\Delta P(t)$	Difference in equivalent number of forage-fed livestock in LULC between project scenario and baseline scenario. *Estimate based on participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[heads]	5 yr
	Rice production in reference region	Harvested area of rice under each of the rice production conditions i in the reference region. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	proportion	5 yr
	Rice production in leakage area	Harvested area of rice under each of the rice production conditions i in the leakage area. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	proportion	5 yr
	Rice production in project area	Harvested area of rice under each of the rice production conditions i in the project area. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	proportion	5 yr
(98)	$\Delta area_{rice}(t,i)$	Difference in harvested area of rice for conditions i between project scenario and baseline scenario for year t. *Calculate based on areas of rice production in the leakage and project areas. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[ha yr^{-1}]	5 yr
	Fuel-efficient stoves acquired	Number of fuel-efficient stoves acquired per year. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	count	AO
	Fuel-efficient stoves used	Number of fuel-efficient stoves effectively used by project participants. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	count	5 yr

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Wood consumption rate with efficient stove	Volume of fuel-wood consumed annually in fuel-efficient stoves per household. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	$[m^3\ yr^{-1}]$	5 yr
	Wood consumption rate with conventional stove	Volume of fuel-wood consumed annually in conventional stoves per household. *Estimate using participatory rural appraisals. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	$[m^3\ yr^{-1}]$	5 yr
	Description of ANR activities	Provide the following elements • Dates, locations, areas, and types of biomass removal (coppicing, removal of invasive species, thinning) • Dates, locations, areas, species, and planting density of enrichment planting. *Record during activity implementation.*	narrative	AO
	ANR tree survival rate	Survival rate of planted or regenerating trees as an ANR activity. *Estimate within the biomass inventory plots inside of the ANR area.*	proportion	5 yr
(78)	$N_{organic,ANR}(t)$	Total amount of organic fertilizer for land preparation of ANR activities during year t. *Record during activity implementation.*	$[Mg\ N\ ha^{-1}\ yr^{-1}]$	AO
(78)	$N_{synthetic,ANR}(t)$	Total amount of synthetic fertilizer for land preparation of ANR activities, adjusted for volatilization as NH_3 and NOx during year t. *Record during activity implementation.*	$[Mg\ N\ ha^{-1}\ yr^{-1}]$	AO
(77)	$area_{fireBiomassLoss,ANR}(t,i)$	Area of biomass removed by controlled burning within ANR stratum i during year t. *Record during activity implementation.*	[ha]	AO
(75)	$area_{biomassLoss,ANR}(t,i)$	Area of biomass removed within ANR stratum i during year t, by coppicing, removing of invasive species, or thinning. *Record during activity implementation.*	[ha]	AO
(75), (77), (73)	$nrANRstrata$	Number of strata within the project area on which ANR activities are proposed. *The area on which ANR activities are proposed is dependent on the ANR management plan implemented by the project proponents. Record during activity implementation.*	count	AO
(72)	$area_{projectAreaWithANR,projectScenario}(t,i)$	Amount of land on which ANR activities are planned under the baseline scenario for year t and in stratum i. *The area on which ANR activities are proposed is dependent on the ANR management plan implemented by the project proponents. Record during activity implementation.*	[ha]	AO

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
(69)	$nrFireClasses$	Number of LULC classes in which fire breaks were installed. *The area on which fire breaks were installed is dependent on the project management plan implemented by the project proponents. Record during activity implementation.*	count	AO
(68)	$nrFuel$	Number of fuel types used (diesel, gasoline, natural gas, propane, etc.). *The area fuel types used is dependent on the project management plan implemented by the project proponents. Record during activity implementation.*	count	AO
(21), (38), (39), (89), (90)	$size_{projectArea}$	Total size of all strata, e.g. the total project area. *The total size of the project area is selected by the project proponents and fixed after the first verification.*	[ha]	fixed after 1st verification
	Evidence of land-tenure strengthening	Information and data on land-tenure strengthening, including: • Dates and reports of all meetings with stakeholders regarding land-tenure status strengthening • Original agreements strengthening the land-tenure status • Dates when the land-tenure status strengthening agreements were signed • Dates and reports of all meetings with stakeholders regarding forest and land-use plans *Record during activity implementation.*	narrative	AO
	Fire prevention labor	Labor hours used to implement the measure fire prevention measure. *Record during activity implementation.*	[hrs]	AO
	NTFP harvest rate	Annual volumes of non-timber forest products extracted. *Estimate using participatory appraisals among participating communities and communities living in the leakage area. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[m^3 yr^{-1}] or [kg yr^{-1}]	AO
	Local NTFP price	Price of non-timber forest products on local markets. *Record during field survey.*	local currency	5 yr
	Location of timber harvesting	Location of timber harvested within the project area. *Record during activity implementation.*	coordinates in shapefile	AO
	Timber harvesting rate	Volume of timber harvested within the project area. *Estimate using participatory appraisals among participating communities and communities living in the leakage area. Sample at least 100 households or 5% of the households in the project area households, whichever is smallest.*	[m^3]	AO
	Location of fuel-wood collection	Location of fuel-wood collected within the project area. *Estimate using participatory appraisals among participating communities and communities living in the leakage area. Sample at least 100 households or 5% of the households in the project area households, whichever is smallest.*	coordinates	AO

Used in Eq.	Parameter	Description	Unit/ Format	Frequency
	Wood harvested for charcoal	Volume of green wood harvested for charcoal production within the project area per forest stratum. *Estimate using participatory appraisals among participating communities and communities living in the leakage area. Sample at least 100 households or 5% of the households in the project area, whichever is smallest.*	[m^3]	AO
	Description of natural disturbance	Provide the following items for every natural disturbance: • Type, i.e. fire/floods/earthquakes/ pest/… • Date • Location and area affected (provide shapefile) • Area within the project area and leakage areas • Estimate of proportion of biomass lost during disturbance *Record every time a natural disturbance decreasing the biomass in the project area is occurring.*	narrative	AO

III.2 Calculation of *Ex-post* Actual Net GHG Emission Reductions

A monitoring report must contain the *ex-post* values of the actual net GHG emission reductions. Actual net NERs must be based on Equation (1); actual VCUs must be based on Equation (2). Update the parameters that are designated as "calculated *ex-post*" in Table 21 with the procedures in this section. After performing all calculations, recalculate Table 20 for every year of the period since the last time verification was sought and the current date.

Table 21. Parameters required to calculate NERs, following Equation (1) with the data source required for this parameter.

Parameter	Source
$\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$	Calculated *ex-post* based on remote sensing data
$\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$\Delta area_{leakageArea,projectScenario}(t,i)$	Calculated *ex-post* based on remote sensing data
$\Delta area_{leakageArea,baselineScenario}(t,i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$\Delta area_{leakageArea,projectScenario}(t,i)$	Calculated *ex-post* based on remote sensing data
$\Delta area_{leakageArea,baselineScenario}(t,i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$u_{classification}$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$u_{inventory}(i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$EF(i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$GHG_{otherLeakageSources}(t)$	Calculated *ex-post* based on monitoring data
$\Delta C(t,i)$	Calculated *ex-post* based on monitoring data
$NAI(i)$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$area_{projectAreaWithANR,baselineScenario(t,i)}$	Fixed *ex-ante*, no *ex-post* adjustment is allowed after first verification
$u_{stratification}$	Fixed *ex-ante*, no *ex-post* adjustment is allowed. Updated during baseline update.
$GHG_{otherLeakageSources}(t)$	Calculated *ex-post* based on monitoring data
$E_{sources,projectArea}(t)$	Calculated *ex-post* based on monitoring data
$E_{sources,leakagePrevention}(t)$	Calculated *ex-post* based on monitoring data
$E_{sources,ANR}(t)$	Calculated *ex-post* based on monitoring data

III.2.1 Calculation of *Ex-ante* GHG Emissions and Changes in Sinks under the Baseline Scenario

This section relates to the following parameters from Equation (1): $\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$, $\Delta area_{leakageArea,baselineScenario}(t,i)$, $\Delta area_{projectAreaWithoutANR,baselineScenario}(t,i)$, $\Delta area_{leakageArea,baselineScenario}(t,i)$, $area_{projectAreaWithANR,baselineScenario(t,i)}$, $u_{classification}$, $u_{inventory}(i)$, $EF(i)$, $NAI(i)$, $u_{stratification}$

Annual baseline land transition rates, emission factors, and uncertainty discounting factors that were approved in the PD or in the latest baseline update must be used. No *ex-post* adjustments of these values are allowed.

III.2.2 Calculation of *Ex-post* GHG Emissions and Changes in Sinks under the Project Scenario inside the Project Area

This section relates to the following parameters from Equation (1): $\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$, $\Delta area_{projectAreaWithANR,projectScenario}(t,i)$, $\Delta C(t,i)$, $E_{sources,projectArea}(t)$, $E_{sources,ANR}(t)$

The changes in carbon sinks under the project scenario in the project area must be calculated based on remote sensing change analysis and field measurements.

- Acquire (a) remote sensing image(s) between validation or the last verification and the current date, and use a similar procedure as used for the baseline to produce (a) land use, land cover, and forest cover map(s). As explained in section II.1.2.4.1, if any part of the project area is covered in clouds or cloud shadows, its GHG accounting should be postponed on that portion of the project area in this monitoring period until cloud-free imagery in this portion of the project area is available. The postponed NERs may be added to the NERs generated in the subsequent monitoring period.
- Compare the changes in between consecutive map(s) since the last time the project was verified and until the current map of land use, land cover, and forest cover. For the project area where no ANR activities were performed, produce (a) land transition matrix/matrices between the consecutive map(s) since the last verification.
- Annualize the land transition matrix/matrices by dividing the land transition rates by the duration in between the two states represented by the maps. The annual rates of land transition changes for the project area on which no ANR activities are planned is $\Delta area_{projectAreaWithoutANR,projectScenario}(t,i)$ in Equation (1).
- Because forest degradation is conservatively omitted on land on which ANR activities are planned, and increases in forest biomass are quantified using CDM-AR-ACM0001 version 03 (see section II.2.4), set all forest degradation and forest regeneration values to zero on the ANR areas. In other words, only retain values for deforestation and reforestation transitions. These are the values for $\Delta area_{projectAreaWithANR,projectScenario}(t,i)$ in Equation (1).
- Calculate values of $\Delta C(t,i)$ using Equation (72). Measure the current aboveground tree biomass density, $B_{AG}(t,i)$, for every stratum i, and calculate the belowground tree biomass density $B_{BG}(t,i)$ using the procedures in section II.1.4.5. Project proponents may choose to increase the number of sampling

plots during the crediting period of previous plots on forest land become deforested or lost through some other cause. An update of the sampling design may be necessary based on updated standard deviations of biomass stock densities.

- Actual emissions from sources under the project scenario within the project area, $E_{sources,projectArea}(t)$ must be calculated using monitored data.
- Actual emissions from sources under the project scenario due to site preparation for ANR activities, $E_{sources,ANR}(t)$ must be calculated using monitored data.
- In the case that credits from avoided degradation were excluded from the generated NERS due to the fact that forest strata cannot be detected with sufficient accuracy, credits from the introduction of fuel-efficient woodstoves may still be issued. Calculate the credits as:

$$WS(t) = 0.75 \cdot proportion_{DG}(fuelWood) \cdot \frac{44}{12} \cdot CF \cdot \rho_{wood} \cdot adoption(fuelEfficientStoves, t) \cdot \left(1 - efficiency(fuelEfficientStoves)\right) \cdot FW_{baseline} \quad (109)$$

where:

$WS(t)$	=	Annual emission reductions from introducing fuel-efficient wood-stoves. [MTCO2e]
$proportion_{DG}(fuelWood)$	=	Proportion of the gradual carbon loss that leads to forest degradation, respectively due to fuel-wood collection. Use the procedure detailed in Table 11 to estimate this number. [-]
CF	=	Carbon fraction of dry matter in dead wood. Use the default value of 0.5.
ρ_{wood}	=	Basic wood density taken from Use default factor from Table GPG-LULUCF 3A.1.9.
$adoption(fuelEfficientStoves, t)$	=	Adoption rate of project activity i which reduces fuel-wood consumption. [-]
$efficiency$	=	Rate at which project activity i reduces fuel-wood consumption. The efficiency must be based on measurements of efficiency by the project proponents in at least 10 randomly selected households. [-]
$FW_{baseline}$	=	Annual volume of fuelwood gathering in the baseline scenario, measured from Social appraisals in the project area before start of the crediting period. At least 100 households or 5% of the households in the project area, whichever is smallest, must be sampled. [m^3 yr^{-1}]

The factor “0.75” is to discount the credits from fuel-efficient woodstoves to remain conservative.

III.2.3 Calculation of *Ex-post* GHG Emissions and Changes in Sinks under the Project Scenario outside the Project Area (Leakage)

This section relates to the following parameters from Equation (1): $\Delta area_{leakageArea,projectScenario}(t,i)$, $GHG_{otherLeakageSources}(t)$, $E_{sources,leakagePrevention}(t)$

Similar to section II.3.1, a distinction is made between the calculation of leakage from geographically constrained drivers and leakage from geographically unconstrained drivers. See section II.3.1 for a distinction between these two categories.

III.2.3.1 Calculation of *Ex-post* Leakage from Geographically Constrained Drivers

The changes in deforestation and forest degradation rates under the project scenario in the leakage area must be calculated using the same remote sensing change analysis as for the project area under the project scenario:

- Acquire (a) remote sensing image(s) between validation or the last verification and the current date, and use a similar procedure as used for the baseline to produce (a) land use, land cover, and forest cover map(s).
- Compare the changes in between consecutive map(s) since the last time the project was verified and until the current map of land use, land cover, and forest cover. For the project area where no ANR activities were performed, produce (a) land transition matrix/matrices between the consecutive map(s) since the last verification.
- Annualize the land transition matrix/matrices by dividing the land transition rates by the duration in between the two states represented by the maps. The annual rates of land transition changes for the leakage area is $\Delta area_{leakageArea,projectScenario}(t,i)$ in Equation (1).

III.2.3.2 Calculation of *Ex-post* Leakage from Geographically Constrained Drivers and Market Leakage

Activity-shifting leakage from geographically unconstrained drivers and market leakage is quantified *ex-post* using a factor approach in which default leakage cancellation factors, set by the VCS (VCS 2007.1, 2008) are used. Use Equation (99) to calculate $GHG_{otherLeakageSources}(t)$.

III.2.3.3 Calculation of *Ex-post* Emission Sources from Leakage Prevention Activities

Actual emissions from sources from leakage prevention activities, $E_{sources,leakagePrevention}(t)$, must be calculated using the equations in section II.3.4, but with monitored data.

III.3 Adjustments to the Project Activities and Sampling Design

III.3.1 Addition of New Project Area before First Verification

As stated before, following VCS 2007.1, 2008 p16-17, new discrete project area parcels (referred to as "new project area") may be integrated into an existing project. Adding new discrete project area parcels can occur only once and must be proposed in the monitoring report of the first verification. After the first verification, the geographical boundaries of the project area are fixed for the rest of the crediting period. The following conditions must be met before new project area can be added:

- The new project area is not larger than 20% of the total project area (including the newly added area).
- The new project area does not affect the outcome of the additionality test.
- The new project area is located within the reference region and follows all requirements and applicability conditions as defined in this methodology.
- A valid leakage belt can be demarcated around the new project area and this leakage belt is still completely located within the reference region.
- The monitoring plan is flexible enough to accommodate the new discrete project area parcels by adding a number of sampling plots proportional to the increase in area.
- A valid baseline for the new areas is added to the monitoring report.

These conditions must be demonstrated in the monitoring report of the fist verification event. In addition, the monitoring report must contain the spatial boundaries of the new discrete project area parcels. The addition of new discrete project area parcels can only occur upon a positive evaluation of the relevant section in the monitoring report by a VCS-accredited verifier.

III.3.2 Adjustments to the ANR Management Plans before First Verification

A detailed management plan of the ANR activities must be included in the PD. The management plan must include all proposed ANR activities and their exact locations. Adjustment of the assisted natural regeneration management plans is allowed until to the first verification. After the first verification, the management plan for ANR activities is fixed.

III.3.3 Update of the Sampling Design, Emission Factors, and Net Annual Increments

It is likely that during the crediting period, permanent forest sampling plots will have to be abandoned due to unforeseen deforestation or natural disasters. When this is the case, new permanent sampling plots must be established. Additionally, the number of permanent sampling plots may be increased simply to decrease $u_{inventory}$ and generate a higher volume of NERs. During the baseline update, the emission factors must be updated based on new measurements of the forest sampling plots similar to the procedure explained in section II.1.4.6.1. In addition, the values used for baseline natural regeneration per forest stratum, $NAI(i)$, must be updated using the following equation, similar to Equation (72):

$$NAI(i) = area_{projectAreaWithANR,projectScenario}(t,i) \cdot \frac{C(t_2,i) - C(t_1,i)}{t_2 - t_1} \tag{110}$$

where:

$area_{projectAreaWithANR,projectScenario}(t,i)$	=	Amount of land on which ANR activities are performed under the baseline scenario for year t and in stratum i.
$C(t_2,i)$ and $C(t_1,i)$	=	Aboveground carbon stock density during years t_2 and t_1 respectively from a stratum on which no ANR activities are planned, but that is similar in conditions as stratum i within the land on which ANR activities are performed. [Mg DM ha^{-1}]
$t_2 - t_1$	=	duration between times 1 and 2. [year]

Therefore, $NAI(i)$ is the empirically observed regeneration rate on strata that are similar to the ones on which ANR activities are performed.

III.4 Updates to Baseline Net GHG Removals by Sinks

Once the baseline (calculated *ex-ante*) is verified, it is locked during the baseline validation period. After this period, a new baseline needs to be calculated and verified. No *ex-post* adjustment of the baseline is allowed. The baseline must be re-assessed and updated at least once every ten years (VCS 2007.1, 2008). The frequency of baseline updates must be fixed in the PD as explained in Step 1C (section II.1.1.3) and approved by the VCS-accredited validator. The baseline update must coincide with a verification event, and must be approved by a verifier.

Baseline updates must follow section II.1, using updated values for all the variables that were noted as "m" in the table of the data to be collected for baseline calculations, with the following exceptions.

- The baseline must be re-calculated for every year of the whole crediting period, meaning from the start of the crediting period onwards and until the end of the crediting period. However, only the forward-looking years are used for calculations of actual NERs; no *ex-post* adjustment of the baseline is allowed. The re-calculation of previous years is necessary to understand the baseline state in the project area at the time of the baseline update.
- The new historical reference period used for the baseline update extends from the original start date of the historical reference period to the time at which the baseline update event is scheduled. In other words, all intermediate values for deforestation and forest degradation rates from the beginning of the historical reference period until the current time must be included. During the crediting period, the graphs of deforestation and forest degradation rates versus time will contain an increasing number of points.
- In addition, after project start, the reference period must exclude project areas and leakage belts. If after project start, new areas within the reference region become protected, these must be excluded from the updated reference region. Protected areas include:
    - National parks that are effectively protected
    - Areas under conservation that are effectively protected
    - Areas under a logging or economic land concession where access is effectively being restricted
    - Large plantations that are effectively protected

- Project proponents must use similar remote sensing data sources and analysis procedures as were used for project design or in the previous baseline update. However, if improved data sources and remote sensing data analysis procedures become available during the crediting period, or if the sensors used for the previous ex-ante baseline calculations become unavailable, it is allowed to change the procedures used previously on the following conditions:
    - Any change in data sources and analysis procedures shall be duly explained and recorded.
    - A formal comparison of the sensors shall be added to the baseline update section within the monitoring report.
    - All points used to calculate the land transition rates in the reference region must be calculated using a sensor that is found compatible with the previous sensor used.
    - In case avoided forest degradation was not included at the start of the crediting period, project proponents may include forest degradation after the start of the crediting period if historical data from a more accurate sensor is used to calculate both historical deforestation and forest degradation rates for at least three points in time, spanning a period of 3-15 years before the time of the baseline update.
- The discounting factors $u_{stratification}$ and $u_{classification}$ must be updated during the baseline update period based on the classification and stratification accuracies for the period until the baseline update.
- The relative reforestation and regeneration rates described in Step 5B (section II.1.5.2) may only be updated using data that is less than 10 years old.
- Summarize all updated baseline land transitions Update the *ex-ante* NERs using the updated baseline estimates, and present an updated version of Table 20 in the monitoring report.

III.5 Conservative Approach and Uncertainties

NERs are calculated by multiplying activity data, area of land that is converted, and emission factors, the decrease in carbon content upon conversion of the land. Both the activity data and the emission factors must be discounted based on the empirically quantified uncertainty of classification into LULC classes, stratification into more narrow forest strata, and biomass inventory using sampling plots, respectively.

- The **activity data** from avoided deforestation must be discounted using $u_{classification}$, the **activity data** from avoided degradation must be discounted using $u_{stratification}$. The $u_{classification}$ and $u_{stratification}$ factors are selected based on the empirically observed accuracy of discerning forest/non-forest classes, and forest biomass classes, respectively. Use Table 8 to select $u_{classification}$ and $u_{stratification}$ based on the accuracies. Note that a minimal accuracy of 90% for the LULC classification and 80% for the forest biomass density stratification must be attained. If stratification does not meet this accuracy threshold, credits from avoided deforestation may still be generated, on the condition that the relevant accuracy threshold is met. However, if the LULC classification does not meet the accuracy threshold, the project is not eligible.
- The **emission factor** must be discounted with $u_{inventory}$, which is based on the half-width of the 95% confidence interval around the mean difference between the two carbon stock densities. This is explained in II.1.4.6. Note that the

minimum desired level of precision for sampling design of biomass inventory is 10%.

Equation (1) outlines the procedure to apply these uncertainty factors.

III.6 Quality Assurance and Quality Control Procedures

To ensure the precise, verifiable and transparent calculation of net NERs, a quality assurance and quality control (QA/QC) procedure shall be implemented.

QA/QC for **field measurements**

- Persons involving in the field measurement work should be fully trained in the field data collection and data analyses.
- List all names of the field teams and the project leader and the dates of the training sessions.
- Record which teams have measured each sampling plot. Record who was responsible for each task.
- Develop Standard Operating Procedures (SOPs) for each step of the field measurements and adhere to these at all times.
- Put a mechanism in place to correct potential errors or inadequacies in the SOPs by a qualified person.
- Verify that plots have been installed and measured correctly, by having approximately 10% of all plots re-measured by an independent team. If the deviation between measurement and re-measurement is larger than 5%, investigate the source of the error, record and correct.

QA/QC for **data entry, documentation and analyses**

- Review the entry of data into the data analyses spreadsheets by an independent source.
- Archived all original data sheets safely. Electronic data shall be backed up adequately on durable media.
- Ensure that all files are named appropriately. Ensure that all database fields, spreadsheet headings or cells are adequately documented in such a way that it can be verified independently.
- Verify calculations for trivial errors such as unit conversion errors.
- If parameters are common between analyses (e.g., emission factors), ensure that consistent values are used.
- Check for consistency among time series data. Identify outliers as soon after the actual measurement as possible. Investigate the cause of the outlying observation, and correct if needed.
- Compare estimates from field measurements or social appraisals with literature values.

QA/QC for **remote sensing analyses**

- Use ground-truthing data to validate the LULC classification and forest stratification. Use confusion matrices and accuracy indices to analyze and quantify the accuracy of the classification.

- Use visual interpretation of high-resolution satellite imagery to complement the medium resolution imagery.
- Check for consistency among time series data. If outliers are present (e.g., in deforestation quantities), analyze the cause and correct if errors were made.
- Compare estimates of deforestation and forest degradation rates with relevant estimates from the literature.

QA/QC for **land use change modeling**

- Split the available data in 2/3 for calibration purposes, and 1/3 for validation purposes. Never use the same data for calibration and validation.
- Report a measure for the accuracy of the land use change model.

Monitoring plan description requirements in PD	**PD Section**
Include the following elements in the monitoring plan:	
• Variables to be tracked continuously o Authority responsible for tracking. o List of variables that will be tracked continuously. o Which potential natural disturbances are foreseen? o Who will record information on natural disturbances? o How will adoption rates and super-acceptance leakage be monitored?	3.3
• Variables to be monitored periodically o Decision on monitoring frequency and rationale. o Decision on the duration of the subsequent monitoring period. o Who will monitor the boundaries of the project regions? o Field inventory ▪ Sample size rationale ▪ Sampling plot size and layout rationale ▪ Sampling plot location ▪ Standard Operations Procedure for field sampling. o Information on agents and drivers ▪ List of variables to be collected. ▪ If a social appraisal needs to be conducted, a list of the variables to be queried.	3.3
• Decision and rationale on the period of baseline validation.	3.2
• All relevant information on natural disturbances & catastrophes.	3.2

Section IV: Lists of Acronyms and References

IV.1 List of Acronyms Used in this Methodology

AFOLU	Agriculture, Forestry, and Other Land Use
ANR	Assisted Natural Regeneration
ARR	Afforestation, Reforestation, and Revegetation
CDM	Clean Development Mechanism
CP	Conference of the Parties
CV	Coefficient of Variation
DBH	Diameter at Breast Height (1.3 m)
DF	Deforestation
DG	Forest Degradation
DM	Dry Matter
DNA	Designated National Authority
EF	Emission Factor
GHG	Greenhouse Gas
GIS	Geographic Information System
GPG-LULUCF	Good Practice Guide for Land Use, Land Use Change and Forestry
GPS	Global Positioning System
GWP	Global Warming Potential
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
LCL	Lower Confidence Limit
LULC	Land Use and Land Cover
Mg	Mega gram = 1 metric tonne
MMU	Minimum Mapping Unit
MT	Metric Tonne
$MTCO_2e$	Metric Tonne of Carbon Dioxide Equivalents
NER	Net Greenhouse Gas Emission Reduction
PD	Project Document
QA/QC	Quality Assurance / Quality Control
RED	Reduced Emissions from Deforestation
REDD	Reduced Emissions from Deforestation and forest Degradation
SOC	Soil Organic Carbon
VCS	Voluntary Carbon Standard
VCU	Voluntary Carbon Unit

IV.2 References:

Achard, F., H.D. Eva, H.J. Stibig, P. Mayaux, J. Gallego, T. Richards, and J.P. Malingreau. 2002. Determination of deforestation rates of the world's humid tropical forests. Science 297:999-1002.

Angelsen, A., and D. Kaimowitz. 1999. Rethinking the causes of deforestation: Lessons from economic models. World Bank Research Observer 14:73-98.

Aukland, L., P.M. Costa, and S. Brown. 2003. A conceptual framework and its application for addressing leakage; the case of avoided deforestation. Climate Policy 3:123–136.

Boer, R., U.R. Wasrin, Perdinan, Hendri, B. D.Dasanto, W. Makundi, J. Hero, M. Ridwan, and N. Masripatin. 2006. Assessment Of Carbon Leakage In Multiple Carbon-Sink Projects: A Case Study In Jambi Province, Indonesia.

Brown, S., F. Achard, and B. Braatz. 2008. Reducing greenhouse gas emissions from deforestation and degradation in developing countries: a sourcebook of methods and procedures for monitoring, measuring and reporting GOFC-GOLD Project Office, Alberta, Canada.

Chomitz, K.M., P. Buys, G. De Luca, T.S. Thomas, and S. Wertz-Kanounnikoff. 2006. At loggerheads. Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests World Bank, Washington, DC.

Congalton, R.G. 1991. A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. Remote Sensing of Environment 37:35-46.

Crutzen, P.J., I. Aselmann, and W. Seiler. 1986. Methane production by domestic animals, wild ruminants, other herbivorous fauna and humans. Tellus 38B:271–284.

De Jong, B.H.J., E. Esquivel Bazan, and S. Quechulpa Montalvo. 2007. Application of the "Climafor" baseline to determine leakage; the case of Scolel Te. Mitigation and Adaptation Strategies for Global Change.

Echeverria, C., Coomes, D.A., Hall, M., Newton, A.C. 2008. Spatially explicit models to analyze forest loss and fragmentation between 1976 and 2020 in southern Chile. Ecological Modeling 212: 439-449.

Freese, F. 1962. Elementary Forest Sampling. USDA Handbook 232 GPO Washington, DC.

Hamburg, S.P. 2000. Simple rule for measuring changes in ecosystem carbon in forestry-offset projects. Mitigation and Adaptation Strategies for Global Change 5:25-37.

IPCC. 2003a. Good Practice Guidance for Land Use, Land Use Change and Forestry Projects (GPG-LULUCF) Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC. 2003b. Definitions and Methodological Options to Inventory Emissions from Direct Human-Induced Degradation of Forests and Devegetation of Other Vegetation Types Intergovernmental Panel on Climate Change, Geneva, Switzerland.

IPCC. 2006. Good Practice Guidance for National Greenhouse Gas Inventories. Chapter 4: Agriculture, Forestry, And Other Land Uses (AFOLU). Intergovernmental Panel On Climate Change, Geneva, Switzerland.

ISO. 2006. ISO 14064-2:2006 - Greenhouse gases — Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements. ISO, Geneva, Switzerland.

Lambin, E.F. 1997. Modelling and monitoring land-cover change processes in tropical regions. Progress in Physical Geography 21:375-393.

Miles, L., and V. Kapos. 2008. Reducing greenhouse gas emissions from deforestation and forest degradation: Global land-use implications. Science 320:1454-1455.

Neeff, T., H. von Luepke, and D. Schoene. 2006. Forests and climate change working paper 4: choosing a forest definition for the clean development mechanism. FAO, Rome, Italy.

Olander, L.P., B.C. Murray, M. Steininger, and H. Gibbs. 2006. Establishing Credible Baselines for Quantifying Avoided Carbon Emissions from Reduced Deforestation and Forest Degradation Duke University, Durham, NC.

Pearson, T., S. Walker, and S. Brown. 2005. Sourcebook for Land use, land-use change and forestry projects BioCarbon Fund of the World Bank, Washington, DC.

Pontius, R.G. 2002. Statistical methods to partition effects of quantity and location during comparison of categorical maps at multiple resolutions. Photogrammetric Engineering and Remote Sensing 68:1041-1049.

Reyes, G., S. Brown, J. Chapman, and A.E. Lugo. 1992. Wood densities of tropical tree species USDA, Washington, DC.

Sathaye, J.A., and K. Andrasko. 2007. Land use change and forestry climate project regional baselines: a review. Mitigation and Adaptation Strategies in Global Change 12:971–1000.

Schlamadinger, B., L. Ciccarese, M. Dutschke, P.M. Fearnside, S. Brown, and D. Murdiyarso. 2005. Should we include avoidance of deforestation in the international response to climate change?, *In* D. Murdiyarso and H. Herawati, eds. Carbon forestry: who will benefit? Proceedings of the Workshop on Carbon Sequestration and Sustainable Livelihoods, Bogor, Indonesia.

Serneels, S. and Lambin, E., 2001. Proximate causes of land-cover change in Narok District, Kenya: a spatial statistical model. Agriculture, Ecosystems and Environment 85, 65–81.

Thompson, S.K. 2000. Sampling. John Wiley and Sons, Hoboken, NJ.

Verburg, P.H., K.P. Overmars, and N. Witte. 2004. Accessibility and land-use patterns at the forest fringe in the northeastern part of the Philippines. The Geographical Journal 170:238–255.

Williams, N.G., McDonnell, M.J., and Seager, E. 2005. Factors influencing the loss of an endangered ecosystem in an urbanizing landscape: a case study of native grasslands from Melbourne, Australia. Landscape and Urban Planning 71, 35–49.